# Virginia Stormwater Management Handbook

*First Edition*
*1999*

**VOLUME I**

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Virginia Department of Conservation and Recreation
*Division of Soil and Water Conservation*

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**COMMONWEALTH of VIRGINIA**

# Virginia Stormwater Management Handbook

*First Edition*
*1999*

## VOLUME I

**Department of Conservation and Recreation**
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Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL AND RECREATIONAL RESOURCES

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The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies.

# TABLE OF CONTENTS

## VOLUME I

Preface / Acknowledgments

## CHAPTER 1. VIRGINIA STORMWATER MANAGEMENT REGULATIONS



## CHAPTER 2. STORMWATER MANAGEMENT and URBAN BMPs



## CHAPTER 3. BMP MINIMUM STANDARDS

## TABLE OF CONTENTS cont.

## TABLE OF CONTENTS cont.

# PREFACE

Welcome to the *Working Draft* of the Virginia Stormwater Management Handbook!! This document is in no way intended to be a trailblazer in the way of new technologies and design standards and methodologies. Rather, the focus was on collecting basic hydrologic, hydraulic, and BMP design principles, most of which have been previously documented in other manuals published within the Chesapeake Bay watershed, and through out the country, and publishing them under one cover. Our number one goal is to promote and develop consistent and effective implementation of stormwater management policies.

So here it is!! This Handbook is a dynamic and evolving resource. Four Technical Bulletins have been developed and are included in the back of the manual. You may wish to insert them in the appropriate chapters or keep them in one place. Additional Technical Bulletins will be developed to provide you with the latest technologies, policies, and guidance. These Technical Bulletins help the Department of Conservation and Recreation (DCR) serve as a clearing house of information on local program development, local program funding ideas and experiences, innovative BMP design, BMP pollutant removal efficiencies, BMP maintenance, ongoing studies, and any other information which would be helpful to Handbook users. Future Technical Bulletins, as well as edits and updates to the Manual, will be available on the DCR website. The best news is that the entire handbook will be available in PDF format on our website: www.dcr.state.va.us

The list of Technical Bulletin topics being requested by our clients is beginning to look like the makings of another Handbook. DCR, however, is committed to providing continual guidance on stormwater issues. We are also interested in your comments. If there are issues which have not been addressed, or issues which deserve more attention, please contact us in writing at:

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## ACKNOWLEDGMENTS

We take our hats off to all those who have developed technical manuals and handbooks before us. There are as many different opinions regarding style and format as there are people who have an interest in hydrology and hydraulics. To quote a famous philosopher: “What a long strange trip its been”.

Many people have played a part in the completion of this Handbook (whether they realize it or not!). Jimmy Edmonds provided great support by taking on the incredible workload of both the Stormwater and Erosion Control Programs during some lean times, always doing whatever was needed while supporting the staff. His efforts and commitment are greatly admired and appreciated. Many others also deserve thanks, however, this Handbook is already thicker than was ever intended. (We slowly bought into the engineering strategy of stormwater reports: thicker is better.) The following list of people hopefully includes everybody involved, both directly and indirectly. Many thanks go to:

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Additional thanks to Richard Claytor, Thomas Schueler, Jennifer Zielinski, and the rest of the staff at the Center for Watershed Protection for all of their trailblazing efforts over the years in documenting incredibly useful information on stormwater BMPs, watershed management, nonpoint source pollution, and the many other topics on which they have written and spoken. Also, thanks to Howard Boggess for agreeing to fix all of our “desktop publishing” mistakes.

Most importantly, thanks go to the members of the Virginia Board of Conservation and Recreation, and the Stormwater Management Subcommittee of the Board (Joseph Maroon, Franklin Hanks, and Susan Moseley) for their tireless efforts in educating themselves on all of the issues surrounding the Stormwater Management Regulations. Also, thanks go to the Stormwater Management Ad-Hoc Committee for their perseverance and commitment in amending the Stormwater Management Regulations.

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# CHAPTER 1

## VIRGINIA STORMWATER MANAGEMENT PROGRAM

# TABLE OF CONTENTS

## 1-1 INTRODUCTION

This Handbook has been developed by the Virginia Department of Conservation and Recreation (DCR) to provide basic guidance for compliance with the Virginia Stormwater Management Regulations. (4VAC3-20 et seq.) The technical material provided within represents some of the more basic types of hydrologic and hydraulic analysis procedures, mostly derived from SCS sources such as the SCS National Engineering Handbook (NEH), and the SCS Engineering Field Manual (EFM), and others. The science of stormwater management analysis is very broad and in no way are the methods and procedures presented here intended to represent the only acceptable way of preparing a stormwater management plan.

**Chapter 1: Virginia Stormwater Management Program**, provides an overview of the various State regulations which address water quality and nonpoint source pollution, as well as the interrelationship among the agencies.

**Chapter 2: Stormwater Management and Urban BMPs**, presents the basic components of stormwater management, as found in the Virginia SWM Regulations, and follows them through the BMP sizing and selection criteria. Most importantly, this Chapter 2 presents the basics of Regional Stormwater Management and Comprehensive Watershed Management.

**Chapter 3: Minimum Standards**, provides the technical design requirements and specifications, and maintenance requirements for stormwater BMPs defined in the Regulations. These criterion were derived from available sources such as the Northern Virginia BMP Handbook, Hampton Roads BMP Handbook, and various other publications, including those from the Metropolitan Washington Council of Governments and the Center for Watershed Protection. These minimum standards represent current, and in some cases innovative, design information pulled together under one cover in order to promote consistency in the design and construction, and therefore the effectiveness, of stormwater BMPs. These BMPs include:

3.01 Earthen Embankments
3.02 Principal Spillways
3.03 Vegetated Emergency Spillway
3.04 Sediment Forebay
3.05 Landscaping
3.06 Retention Basins
3.07 Extended Detention Basin
3.08 Detention Basin
3.09 Constructed Wetlands
3.10 Infiltration Practices
3.11 Bio-Retention
3.12 Sand Filters
3.13 Grassed Swale
3.14 Vegetated Filter Strip
3.15 Manufactured BMP Systems

**Chapter 4: Hydrologic Methods**, presents four methods for conducting a hydrologic analysis and determining the peak discharge from a watershed or drainage area. These methods include the Rational Method, Modified Rational Method, SCS TR-55 Graphical Peak Discharge Method and Tabular Hydrograph Method. Also included is a basic overview of various types of design hydrographs used in stormwater modeling.

**Chapter 5: Engineering Calculations**, provides very detailed calculation procedures for designing an impoundment BMP using standard hydraulic equations. These procedures include storage volume requirements, water quality and channel erosion control volume calculations, extended detention calculations, principal spillway and emergency spillway design, anti-seep collar design, outlet protection, riser floatation calculations, and water quality calculation procedures.

**Chapter 6: Example Problems**, provides some design examples including hydrologic and hydraulic analyses.

## 1-2 VIRGINIA STORMWATER MANAGEMENT PROGRAM

The 1998 amendments to the Virginia Stormwater Management (SWM) Regulations (4 VAC 3-20-10 et. seq.) reflect an on-going evolution in the definition and role of stormwater management. The initial goal of the amendment was to develop a more “user friendly” regulation; one which allowed flexibility for local program adoption, while also maintaining a solid framework of technical criteria. During the amendment process, legislative studies on the efficiency and consistency of the stormwater management and permitting policies of the Commonwealth provided additional guidance in the area of regulatory consistency. Providing consistent technical criteria for the water quality related programs in Virginia soon became a goal as well. To satisfy the these two goals, the technical criteria within the amended SWM regulations is divided into components: *Water Quality*, *Stream Channel Erosion*, and *Flooding*.

Water Quality

The water quality component reflects consistency between the Virginia SWM Regulations (DCR), The Chesapeake Bay Preservation Act (CBPA) and regulations (CBLAD), and the Virginia Pollution Discharge Elimination System (VPDES) permit (DEQ).

***The reader should note that the land disturbing thresholds for compliance with these other water quality programs are independent of the SWM regulations: A VPDES permit is required for various industrial activities (including construction activities of 5 acres or more) and CBPA local regulatory compliance is required for projects of a certain size and/or in certain locations (refer to the local ordinance). Once it is determined that compliance with one of these water quality related programs is required, then the stormwater management regulations technical criteria for water quality (4 VAC 3-20-11) provides the consistent criteria for compliance.***

Stream Channel Erosion

The stream channel erosion component of the SWM Regulations (4 VAC 3-20-81) incorporates the technical provisions of stormwater runoff component of the Erosion and Sediment Control Regulations (Minimum Standard 19, 4 VAC 50-30-40.19) as required by law. This component will be the subject of significant scrutiny as we try to further develop an appropriate technical criteria for stream channel erosion control. The challenge is the variable nature of stream channel hydraulics and hydrologic modeling. As the technical criteria is expanded to define the analysis and required solutions, we lose the emphasis on the engineers’ ability and responsibility to determine the appropriate level of design for stream channel protection. An alternative would be to simply require that “downstream channels and properties be protected from erosion and damage due to increase in volume, velocity, and peak flow rate”. The engineer would then be responsible for determining what level of control is needed to satisfy the requirement. On the other hand, requiring a full analysis of the channel geomorphology in order to establish the protection criteria would probably be too complex of an analysis, with few people qualified to review it.

The amended SWM regulations provide an alternative design criteria that has been found to be more effective in preventing downstream channel erosion: extended detention of the runoff from the 1-year frequency 24-hour storm. This criteria effectively reduces the runoff flow rate and velocity from a wide range of storms to less than the critical velocity. Further updates and guidance on the channel erosion component will be provided.

Flexible Adoption

The most significant amendment to the regulations is the flexible adoption of the stormwater components. A locality may now adopt individual components for local implementation. During the development of these amendments, this flexible adoption was referred to as a *cafeteria style* approach: choose the desired components from the "menu" of options. **However, any local SWM program adopted pursuant to the Stormwater Management Law (Title 10.1, Chapter 6, Article 1.1) must, at a minimum, contain the Flooding component (4VAC3-20-85).**

Administrative Procedures and Reporting

Other elements within the Regulations which caused concern on the part of localities interested in adopting a program were the Administrative Procedures which address stormwater management plan submission and review, and local program reporting. DCR acknowledged that our intent is not to supersede any local program development review process. State law does mandate a maximum review time of 60 days, with communication of the review to the applicant in writing. A survey of local program administrative procedures indicated that the actual review times, whether as required by local ordinance or by the level of development, were actually much less than the required 60 day maximum.

The issue of local program reporting was evaluated in light of the General Assembly requirement of an annual report on the extent to which local stormwater management programs have reduced nonpoint source pollution and mitigated the effects of localized flooding. Local government officials were wary of a reporting burden draining available staff time. DCR reviewed the type of information which was needed to compile the annual report to the General Assembly and determined the level of reporting to be a simple accounting of stormwater BMPs approved through the development review process or otherwise implemented in the locality. Additional information, such as monitoring studies, regional watershed plan studies and implementation, are certainly considered helpful in compiling a report to the General Assembly, however, not every locality will have such information. Again, a local program survey indicated that most existing local review and approval procedures do contain a simple accounting of what has been approved. Therefore, DCR amended the Reporting section of the Regulations (4VAC3-20-251) to ask local programs to voluntarily submit an annual report to the Department, as well as indicate the type of information which would be appropriate. The basis for this was that if most local programs are already compiling the type of information needed for the annual report, as the local program survey indicated, than the reporting of that information should not be burden. For localities that are just starting a program, DCR will commit to providing a simple record keeping system to help document the stormwater management BMPs and associated information.

In summary, the amendments to the Stormwater Management Regulations have made the adoption of a local program extremely simple and unburdonsome. Consider a local government currently operating, as required by law, an Erosion and Sediment Control Program with MS-19 requirements, and a Chesapeake Bay Preservation Act (CBPA) ordinance. MS-19 requirements satisfy the Stream Channel Erosion component of the Stormwater Management Regulations, and the water quality provisions within the CBPA ordinance satisfy the water quality component of the Stormwater Regulations. If the locality also has a flood control requirement (10-year storm, 25-year storm, etc.), than that locality is in full compliance with the State minimum technical requirements for a local stormwater management program. Without changing any of the actual duties or requirements mandated by the local ordinance, the locality may simply reference the authority for their combined program as the Virginia Stormwater Management Law, and thereby operate under the simple umbrella of enabling authority offered by the Stormwater Management Law. (It may be advisable to consolidate the various components into one section or chapter of the local ordinance for simplicity.)

There are many variations of the above example where localities are currently operating under fragmented enabling authority, and can now amend their ordinance to reference the Stormwater Management Law. The Department will periodically review these programs to insure consistency in implementation. The purpose of the review is to help the Department promote consistency in stormwater management policies across the commonwealth, as directed by the General Assembly, as well as help the local program maintain effective implementation of the technical criteria.

State Agency Compliance with Local Programs

Another incentive for local programs to adopt a State Stormwater Management Program is the ability to require state agency projects to comply with the local requirements. This can be especially important if a regional (watershed-wide) plan has been adopted. The Regulations allow for a local program to request, in writing, that the Department consider the local program requirements when reviewing state agency plans. Further, the regulations require that state agencies, to the maximum extent practicable, comply with any local stormwater management program technical criteria adopted pursuant to the Act, and that it shall be the responsibility of the state agency to demonstrate that the local program requirements are not practical for the project under consideration. (4VAC3-20-210).
Experience has indicated that this cooperation between local programs and state agencies has resulted in a win-win deal for the locality and the state agency, and in most cases resulted in more effective BMP implementation. Localities must notify DCR of their desire to have state agency plans comply with the local program technical requirements or investigate participating in a local regional SWM program.

## 1-3 VIRGINIA STORMWATER MANAGEMENT LAW and REGULATIONS

**The following is the complete, edited text of Title 10.1, Chapter 6, Article 1.1 of the Code of Virginia as amended through 1998. Please refer to the Code of Virginia for an official copy of the Law.**

### § 10.1-603.1. Cooperative state-local program.

The General Assembly has determined that the lands and waters of the Commonwealth are great natural resources; that as a result of intensive land development and other land use conversions, degradation of these resources frequently occurs in the form of water pollution, stream channel erosion, depletion of groundwater resources, and more frequent localized flooding; that these impacts adversely affect fish, aquatic life, recreation, shipping, property values and other uses of lands and waters; that existing authorities under the Code of Virginia do not adequately address all of these impacts. Therefore the General Assembly finds it in the public interest to enable the establishment of stormwater management programs.

### § 10.1-603.2. Definitions.

As used in this article, unless the context requires a different meaning:

*"Applicant"* means any person submitting a stormwater management plan for approval.

*"Board"* means the Board of Conservation and Recreation.

*"Department"* means the Department of Conservation and Recreation.

*"Flooding"* means a volume of water which is too great to be confined within the banks or walls of the stream, water body or conveyance system and which overflows onto adjacent lands, causing or threatening damage.

*"Land development"* or *"land development project"* means a manmade change to the land surface that potentially changes its runoff characteristics.

*"Linear development project"* means a land development project that is linear in nature such as, but not limited to, (I) the construction of electric and telephone utility lines, and natural gas pipelines; (ii) construction of tracks, rights-of-way, bridges, communication facilities and other related structures of a railroad company; and (iii) highway construction projects.

*"Local stormwater management program"* or "local program" means a statement of the various methods employed by a locality to manage the runoff from land development projects and may include such items as local ordinances, policies and guidelines, technical materials, inspection, enforcement, and evaluation.

*"Nonpoint source pollution"* means pollution whose sources cannot be pinpointed but rather is washed from the land surface in a diffuse manner by stormwater runoff.

*"Runoff"* means that portion of precipitation that is discharged across the land surface or through conveyances to one or more waterways.

*"Stormwater management plan"* or *"plan"* means a document containing material for describing how existing runoff characteristics will be maintained by a land development project.

*"Subdivision"* means the same as defined in §15.1-465.

*"Watershed"* means a defined land area drained by a river or stream or system of connecting rivers or streams such that all surface water within the area flows through a single outlet.

**§ 10.1-603.3. Counties, cities and towns may by ordinance establish stormwater management programs as a local option; effective date**

Each locality may, by ordinance, to be effective on or after July 1, 1990, establish a local stormwater management program which shall include, but is not limited to, the following:

1. Consistency with regulations promulgated in accordance with provisions of this article;

2. Provisions for long-term responsibility for and maintenance of stormwater management control devices and other techniques specified to manage the quality and quantity of runoff; and

3. Provisions for the integration of locally adopted stormwater management programs with local erosion and sediment control, flood insurance, flood plain management and other programs requiring compliance prior to authorizing construction in order to make the submission and approval of plans, issuance of permits, payment of fees, and coordination of inspection and enforcement activities more convenient and efficient both for the local governments and those responsible for compliance with the programs.

**§ 10.1-603.4. Development of regulations.**

The Board is authorized to promulgate regulations which specify minimum technical criteria and administrative procedures for stormwater management programs in Virginia. In order to inhibit the deterioration of existing waters and waterways, the regulations shall:

1. Require that state and local programs maintain after-development runoff rate of flow, as nearly as practicable, as the pre-development runoff characteristics;

2. Establish minimum design criteria for measures to control nonpoint source pollution and

localized flooding, and incorporate the stormwater management regulations promulgated pursuant to the Virginia Erosion and Sediment Control Law, Article 4 (§10.1-560 et seq.) of Chapter 5 of this title, as they relate to the prevention of stream channel erosion. These criteria shall be periodically modified as required in order to reflect current engineering methods;

3. Require the provision of long-term responsibility for and maintenance of stormwater management control devices and other techniques specified to manage the quality and quantity of runoff; and

4. Require as a minimum the inclusion in local programs of certain administrative procedures which include, but are not limited to, specifying the time period within which a local government which has adopted a stormwater management program must grant written approval of a plan, the conditions under which approval shall be granted, the procedures for communicating disapproval, the conditions under which an approved plan may be changed and requirements for inspection of approved projects.

**§ 10.1-603.5. State agency projects.**

A. After January 1, 1991, a state agency may not undertake any land clearing, soil movement, or construction activity involving soil movement or land development unless the agency has submitted and obtained approval of a stormwater management plan from the Department. In lieu of such a plan, the agency may annually submit stormwater management standards and specifications.

B. Notwithstanding the provisions of this article, all state agencies shall comply with the stormwater management provisions of the Erosion and Sediment Control Law, Article 4 (§10.1-560 et seq.) of Chapter 5 of this title, and related regulations. The Department shall perform random site inspections to assure compliance with this article, the Erosion and Sediment Control Law and regulations promulgated thereunder.

C. The Department shall have thirty days in which to comment on the stormwater management plan, and its recommendations shall be binding on the state agency or the private business hired by the state agency. Individual approval of separate projects is not necessary when annually approved standards and specifications have been approved.

As on-site changes occur, the state agency shall submit changes in the stormwater management plan to the Department.

The state agency responsible for the land-disturbing activity shall ensure compliance with the approved plan or specifications.

**§ 10.1-603.6. Involvement of the Department with local programs.**

A. The Department shall provide technical assistance, training, research, and coordination in stormwater management technology to the local governments consistent with the purposes of this article.

B. The Department is authorized to review the plan for any project with real or potential interjurisdictional impacts upon the request of one of the involved localities to determine that the plan is consistent with the provisions of this article. Any such review shall be completed and a report submitted to each locality involved within ninety days of such request.

**§ 10.1-603.7. Authorization for more stringent regulations.**

Localities are authorized to adopt more stringent stormwater management regulations than those necessary to ensure compliance with the Board's minimum regulations, with the exception of regulations related to plan approval, provided that the more stringent regulations are based upon the findings of local comprehensive watershed management studies and that prior to adopting more stringent regulations a public hearing is held after giving due notice.

**§ 10.1-603.8. Regulated activities; submission and approval of a control plan; security for performance; exemptions.**

A. Except as provided in §10.1-603.5, after the adoption of a local ordinance, a person shall not develop any land for residential, commercial, industrial, or institutional use in that locality until he has submitted a stormwater management plan to the locality that has jurisdiction and has obtained approval of the plan from that locality. The plan may include appropriate maps, mathematical calculations, detail drawings and a listing of all major decisions to assure that the entire unit or units of land will be so treated to achieve the objectives of the local program. Prior to issuance of any permit, the locality may also require an applicant to submit a reasonable performance bond with surety, cash escrow, letter of credit, any combination thereof, or such other legal arrangement acceptable to the locality, to ensure that measures could be taken by the locality at the applicant's expense should he fail, after proper notice, within the time specified to initiate or maintain appropriate actions which may be required of him by the approved stormwater management plan as a result of his land-development project. If the locality takes such action upon such failure by the applicant, the agency may collect from the applicant for the difference should the amount of the reasonable cost of such action exceed the amount of the security held. Within sixty days of the completion of the requirements of the approved stormwater management plan, such bond, cash escrow, letter of credit or other legal arrangement, or the unexpended or unobligated portion thereof, shall be refunded to the applicant or terminated. These requirements are in addition to all other provisions of law relating to the issuance of such plans and are not intended to otherwise affect the requirements for such plans.

B. Notwithstanding any other provisions of this article, the following activities are exempt:

1. Permitted surface or deep mining operations and projects, or oil and gas operations and projects conducted under the provisions of Title 45.1;

2. Tilling, planting or harvesting of agricultural, horticultural, or forest crops;

3. Single-family residences separately built and not part of a subdivision, including additions or modifications to existing single-family detached residential structures;

4. Land development projects that disturb less than one acre of land area; however, the governing body of a locality which has adopted a stormwater management program may reduce this exception to a smaller area of disturbed land or qualify the conditions under which this exception shall apply; and

5. Linear development projects, provided that (I) less than one acre of land will be disturbed per outfall or watershed, (ii) there will be insignificant increases in peak flow rates, and (iii) there are no existing or anticipated flooding or erosion problems downstream of the discharge point.

**§ 10.1-603.9. Approved plan required for issuance of grading, building, or other permits.**

Upon the adoption of a local ordinance no grading, building or other permit shall be issued for a property unless a stormwater management plan has been approved that is consistent with the local program and this article and unless the applicant has certified that all land clearing, construction, land development and drainage will be done according to the approved plan.

**§ 10.1-603.10. Recovery of administrative costs.**

Any locality which administers a stormwater management program may charge applicants a reasonable fee to defray the cost of program administration, including costs associated with plan review, issuance of permits, periodic inspection for compliance with approved plans, and necessary enforcement, provided that charges for such costs are not made under any other law, ordinance or program. The fee shall not exceed an amount commensurate with the services rendered and expenses incurred or $1,000, whichever is less.

**§ 10.1-603.11. Monitoring, reports and inspections.**

A. The plan-approving authority or, if a permit is issued in connection with land-disturbing activities which involve the issuance of a grading, building, or other permit, the permit-issuing authority (I) shall provide for periodic inspections of the installation of stormwater management measures and (ii) may require monitoring and reports from the person responsible for carrying out the plan, to ensure compliance with the approved plan and to determine whether the measures required in the plan provide effective stormwater management. The owner, occupier or operator shall be given notice of the inspection and an opportunity to accompany the inspectors. If the permit-issuing authority or plan-approving authority determines that there is a failure to comply with the plan, notice shall be served upon the permittee or person responsible for carrying out the plan by registered or certified mail to the address specified in the permit application or in the plan certification, or by delivery at the site of the development activities to the agent or employee supervising such activities. Where the plan-approving authority serves notice, a copy of the notice shall also be sent to the issuer of the permit. The notice shall specify the measures needed to comply with the plan and shall specify the time within which such measures shall be completed. Upon failure to comply within the time specified, the permit may be revoked and the permittee or person responsible for carrying out the plan shall be deemed to be in violation of this article and upon conviction shall be subject to the penalties provided by §10.1-603.14.

B. Notwithstanding subsection A of this section, the following may be applied:

1. Where a county, city, or town administers the local control program and the permit-issuing authority and the plan-approving authority are not within the same local government department, the locality may designate one department to inspect, monitor, report and ensure compliance.

2. Where a permit-issuing authority has been established, and such authority is not vested in an employee or officer of local government but in the commissioner of revenue or some other person, the locality shall exercise the responsibilities of the permit-issuing authority with respect to monitoring, reports, inspections, and enforcement unless such responsibilities are transferred as provided for in this section.

**§ 10.1-603.12. Department to review local and state agency programs.**

A. The Department shall periodically conduct a comprehensive review and evaluation of the effectiveness of each local government's and state agency's stormwater management program. The review shall include an assessment of the extent to which the program has reduced nonpoint source pollution and mitigated the detrimental effects of localized flooding. A summary of these reviews and evaluations shall be submitted annually to the General Assembly.

B. If, after such a review and evaluation, a local government is found to have a program which does not comply with the provisions of this article or regulations promulgated thereunder, the Department may issue an order requiring that necessary corrective action be taken within a reasonably prescribed time.

**§ 10.1-603.13. Appeals of decisions of counties, cities or towns.**

A. An appeal from a decision of a locality concerning an application for approval or disapproval of a stormwater management plan may be taken by the applicant, or any aggrieved party authorized by law, within thirty days after the rendering of such a decision of the locality, to the circuit court of the jurisdiction in which the land development project is located.

B. Judicial review shall be on the record previously established and shall otherwise be in accordance with the provisions of the Administrative Process Act (§9-6.14:1 et seq.).

**§ 10.1-603.14. Penalties, injunctions and other legal actions.**

Any person who violates any provision of a local ordinance or program adopted pursuant to the authority of this article shall be guilty of a misdemeanor and shall be subject to a fine not exceeding $1,000 or up to thirty days imprisonment for each violation or both. Such a local ordinance may also include the following sanctions:

1. A locality operating its own program may apply to the circuit court in any jurisdiction wherein the land lies to enjoin a violation or a threatened violation of the provisions of this article or of the local ordinance without the necessity of showing that an adequate remedy at law does not exist.

2. Without limiting the remedies which may be obtained in this section, a locality operating its own program may bring a civil action against any person for violation of any ordinance or any condition of a permit, or any provision of a local program adopted pursuant to this article. The action may seek the imposition of a civil penalty of not more than $2,000 against the person for each violation.

3. With the consent of any person who has violated or failed, neglected or refused to obey any ordinance or any condition of a permit or any provision of a local program adopted pursuant to this article, the administrator of the local program may provide, in an order issued by the administrator against such person, for the payment of civil charges for violations in specific sums, not to exceed the limit specified in subdivision 2 of this section. Such civil charges shall be instead of any appropriate civil penalty which could be imposed under subdivision 2.

**§ 10.1-603.15. Cooperation with federal and state agencies.**

Localities operating their own programs and the Department are authorized to cooperate and enter into agreements with any federal or state agency in connection with plans for stormwater management.

## 1-4 VIRGINIA STORMWATER MANAGEMENT REGULATIONS

**The following is a complete text of the Virginia Stormwater Management Regulations 4VAC3-20 amended by the Board of Conservation and Recreation, effective March 5, 1998**

PART I.
GENERAL.

**4 VAC 3-20-10. Definitions.**

The following words and terms used in this chapter have the following meanings, unless the context clearly indicates otherwise.

*"Act"* means Article 1.1 (§ 10.1-603.1 et seq.) of Chapter 6 of Title 10.1 of the Code of Virginia.

*"Adequate channel"* means a channel that will convey the designated frequency storm event without overtopping the channel banks nor causing erosive damage to the channel bed or banks.

*"Applicant"* means any person submitting a stormwater management plan for approval.

*"Aquatic bench"* means a 10- to 15-foot wide bench around the inside perimeter of a permanent pool that ranges in depth from zero to 12 inches. Vegetated with emergent plants, the bench augments pollutant removal, provides habitats, conceals trash and water level fluctuations, and enhances safety.

*"Average land cover condition"* means a measure of the average amount of impervious surfaces within a watershed, assumed to be 16%. Note that a locality may opt to calculate actual watershed-specific values for the average land cover condition based upon 4 VAC 3-20-101.

*"Best management practice (BMP)"* means a structural or nonstructural practice which is designed to minimize the impacts of development on surface and groundwater systems.

*"Bioretention basin"* means a water quality BMP engineered to filter the water quality volume through an engineered planting bed, consisting of a vegetated surface layer (vegetation, mulch, ground cover), planting soil, and sand bed, and into the in-situ material.

*"Bioretention filter"* means a bioretention basin with the addition of a sand filter collector pipe system beneath the planting bed.

*"Board"* means the Board of Conservation and Recreation.

*"Channel"* means a natural or manmade waterway.

*"Constructed wetlands"* means areas intentionally designed and created to emulate the water quality improvement function of wetlands for the primary purpose of removing pollutants from stormwater.

*"Department"* means the Department of Conservation and Recreation.

*"Development"* means a tract of land developed or to be developed as a unit under single ownership or unified control which is to be used for any business or industrial purpose or is to contain three or more residential dwelling units.

*"Director"* means the Director of the Department of Conservation and Recreation.

*"Flooding"* means a volume of water that is too great to be confined within the banks or walls of the stream, water body or conveyance system and that overflows onto adjacent lands, causing or threatening damage.

*"Grassed swale"* means an earthen conveyance system which is broad and shallow with erosion resistant grasses and check dams, engineered to remove pollutants from stormwater runoff by filtration through grass and infiltration into the soil.

*"Impervious cover"* means a surface composed of any material that significantly impedes or prevents natural infiltration of water into soil. Impervious surfaces include, but are not limited to, roofs, buildings, streets, parking areas, and any concrete, asphalt, or compacted gravel surface.

*"Infiltration facility"* means a stormwater management facility which temporarily impounds runoff and discharges it via infiltration through the surrounding soil. While an infiltration facility may also be equipped with an outlet structure to discharge impounded runoff, such discharge is normally reserved for overflow and other emergency conditions. Since an infiltration facility impounds runoff only temporarily, it is normally dry during nonrainfall periods. Infiltration basin, infiltration trench, infiltration dry well, and porous pavement shall be considered infiltration facilities.

*"Inspection"* means an on-site review of the project's compliance with the approved plan, the local stormwater management program, and any applicable design criteria.

*"Land development"* or *"land development project"* means a manmade change to, or construction on, the land surface, except as exempted in the Stormwater Management Act, § 10.1-603.8 B of the Code of Virginia, that changes its runoff characteristics.

*"Linear development project"* means a land development project that is linear in nature such as, but not limited to, (i) the construction of electric and telephone utility lines, and natural gas pipelines; (ii) construction of tracks, rights-of-way, bridges, communication facilities and other related structures of a railroad company; and (iii) highway construction projects.

*"Local stormwater management program"* or *"local program"* means a statement of the various methods adopted pursuant to the Act and implemented by a locality to manage the runoff from land development projects and shall include an ordinance with provisions to require the control of after-development stormwater runoff rate of flow, the proper maintenance of stormwater management facilities, and minimum administrative procedures consistent with this chapter.

*"Locality"* means a county, city, or town.

*"Nonpoint source pollution"* means contaminants such as sediment, nitrogen and phosphorous, hydrocarbons, heavy metals, and toxics whose sources cannot be pinpointed but rather are washed from the land surface in a diffuse manner by stormwater runoff.

*"Nonpoint source pollutant runoff load"* or *"pollutant discharge"* means the average amount of a particular pollutant measured in pounds per year, delivered in a diffuse manner by stormwater runoff.

*"Percent impervious"* means the impervious area within the site divided by the area of the site multiplied by 100.

*"Person"* means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, county, city, town or other political subdivision of the Commonwealth, any interstate body or any other legal entity.

*"Planning area"* means a designated portion of the parcel on which the land development project is located. Planning areas shall be established by delineation on a master plan. Once established, planning areas shall be applied consistently for all future projects.

*"Post-development"* refers to conditions that reasonably may be expected or anticipated to exist after completion of the land development activity on a specific site or tract of land.

*"Pre-development"* refers to the conditions that exist at the time that plans for the land development of a tract of land are approved by the plan approval authority. Where phased development or plan approval occurs (preliminary grading, roads and utilities, etc.), the existing conditions at the time *prior to* the first item being approved or permitted shall establish pre-development conditions.

*"Regional (watershed-wide) stormwater management facility"* or *"regional facility"* means a facility or series of facilities designed to control stormwater runoff from a specific watershed, although only portions of the watershed may experience land development.

*"Regional (watershed-wide) stormwater management plan"* or *"regional plan"* means a document containing material describing how runoff from open space, existing development and future planned development areas within a watershed will be controlled by coordinated design and implementation of regional stormwater management facilities.

*"Runoff"* or *"stormwater runoff"* means that portion of precipitation that is discharged across the land surface or through conveyances to one or more waterways.

*"Sand filter"* means a contained bed of sand which acts to filter the first flush of runoff. The runoff is then collected beneath the sand bed and conveyed to an adequate discharge point or infiltrated into the in-situ soils.

*"Shallow marsh"* means a zone within a stormwater extended detention basin that exists from the surface of the normal pool to a depth of six to 18 inches, and has a large surface area and, therefore, requires a reliable source of baseflow, groundwater supply, or a sizeable drainage area,

to maintain the desired water surface elevations to support emergent vegetation.

*“Site”* means the parcel of land being developed, or a designated planning area in which the land development project is located.

*"State project"* means any land development project which is undertaken by any state agency, board, commission, authority or any branch of state government, including state supported institutions of higher learning.

*"Stormwater detention basin"* or *"detention basin"* means a stormwater management facility which temporarily impounds runoff and discharges it through a hydraulic outlet structure to a downstream conveyance system. While a certain amount of outflow may also occur via infiltration through the surrounding soil, such amounts are negligible when compared to the outlet structure discharge rates and are, therefore, not considered in the facility's design. Since a detention facility impounds runoff only temporarily, it is normally dry during nonrainfall periods.

*"Stormwater extended detention basin"* or *“extended detention basin”* means a stormwater management facility which temporarily impounds runoff and discharges it through a hydraulic outlet structure over a specified period of time to a downstream conveyance system for the purpose of water quality enhancement or stream channel erosion control. While a certain amount of outflow may also occur via infiltration through the surrounding soil, such amounts are negligible when compared to the outlet structure discharge rates and, therefore, are not considered in the facility's design. Since an extended detention basin impounds runoff only temporarily, it is normally dry during nonrainfall periods.

*“Stormwater extended detention basin-enhanced”* or *“extended detention basin-enhanced”* means an extended detention basin modified to increase pollutant removal by providing a shallow marsh in the lower stage of the basin.

*"Stormwater management facility"* means a device that controls stormwater runoff and changes the characteristics of that runoff including, but not limited to, the quantity and quality, the period of release or the velocity of flow.

*"Stormwater management plan"* or *"plan"* means a document containing material for describing how existing runoff characteristics will be affected by a land development project and methods for complying with the requirements of the local program or this chapter.

*"Stormwater retention basin"* or *"retention basin"* means a stormwater management facility which includes a permanent impoundment, or normal pool of water, for the purpose of enhancing water quality and, therefore, is normally wet, even during nonrainfall periods. Storm runoff inflows are may be temporarily stored above this permanent impoundment for the purpose of reducing flooding, or stream channel erosion.

*“Stormwater retention basin I”* or *“retention basin I”* means a retention basin with the volume of the permanent pool equal to three times the water quality volume.

*"Stormwater retention basin II"* or *"retention basin II"* means a retention basin with the volume of the permanent pool equal to four times the water quality volume.

*"Stormwater retention basin III"* or *"retention basin III"* means a retention basin with the volume of the permanent pool equal to four times the water quality volume with the addition of an aquatic bench.

*"Subdivision"* unless otherwise defined in a local ordinance adopted pursuant to § 15.1-465 of the Code of Virginia, means the division of a parcel of land into three or more lots or parcels of less than five acres each for the purpose of transfer of ownership or building development, or, if a new street is involved in such division, any division of a parcel of land. The term includes resubdivision and, when appropriate to the context, shall relate to the process of subdividing or to the land subdivided.

*"Vegetated filter strip"* means a densely vegetated section of land engineered to accept runoff as overland sheet flow from upstream development. It shall adopt any natural vegetated form, from grassy meadow to small forest. The vegetative cover facilitates pollutant removal through filtration, sediment deposition, infiltration and absorption, and is dedicated for that purpose.

*"Water quality volume"* means the volume equal to the first 1/2 inch of runoff multiplied by the impervious surface of the land development project.

*"Watershed"* means a defined land area drained by a river, stream or drainage ways or system of connecting rivers, streams, or drainage ways such that all surface water within the area flows through a single outlet.

**4 VAC 3-20-30. Purposes.**

The purposes of this chapter are to provide a framework for the administration, implementation and enforcement of the Act, while at the same time providing flexibility for innovative solutions to stormwater management issues.

**4 VAC 3-20-40. Applicability.**

This chapter is applicable to:

1. Every locality that establishes a local stormwater management program; and
2. Every state project.

PART II.
TECHNICAL CRITERIA.

**4 VAC 3-20-50. Applicability.**

This part specifies technical criteria for localities that establish a local stormwater management program and for state projects.

**4 VAC 3-20-60. General.**

A. Determination of flooding and channel erosion impacts to receiving streams due to land development projects shall be measured at each point of discharge from the development project and such determination shall include any runoff from the balance of the watershed which also contributes to that point of discharge.

B. The specified design storms shall be defined as either a 24-hour storm using the rainfall distribution recommended by the U.S. Soil Conservation Service when using U.S. Soil Conservation Service methods or as the storm of critical duration that produces the greatest required storage volume at the site when using a design method such as the Modified Rational Method.

C. For purposes of computing runoff, all pervious lands in the site shall be assumed prior to development to be in good condition (if the lands are pastures, lawns, or parks), with good cover (if the lands are woods), or with conservation treatment (if the lands are cultivated); regardless of conditions existing at the time of computation.

D. Construction of stormwater management facilities or modifications to channels shall comply with all applicable laws and regulations. Evidence of approval of all necessary permits shall be presented.

E. Impounding structures that are not covered by the Impounding Structure Regulations (4 VAC 50-20-10 et seq.) shall be engineered for structural integrity during the 100-year storm event.

F. Pre-development and post-development runoff rates shall be verified by calculations that are consistent with good engineering practices.

G. Outflows from a stormwater management facility shall be discharged to an adequate channel, and velocity dissipators shall be placed at the outfall of all stormwater management facilities and along the length of any outfall channel as necessary to provide a nonerosive velocity of flow from the basin to a channel.

H. Proposed residential, commercial, or industrial subdivisions shall apply these stormwater management criteria to the land development as a whole. Individual lots in new subdivisions shall not be considered separate land development projects, but rather the entire subdivision shall be considered a single land development project. Hydrologic parameters shall reflect the ultimate land development and shall be used in all engineering calculations.

I. All stormwater management facilities shall have a maintenance plan which identifies the owner and the responsible party for carrying out the maintenance plan.

J. Construction of stormwater management impoundment structures within a Federal Emergency Management Agency (FEMA) designated 100-year floodplain shall be avoided to the extent possible. When this is unavoidable, all stormwater management facility construction shall be in compliance with all applicable regulations under the National Flood Insurance Program, 44 CFR Part 59.

K. Natural channel characteristics shall be preserved to the maximum extent practicable.

L. Land development projects shall comply with the Virginia Erosion and Sediment Control Act and attendant regulations.

**4 VAC 3-20-71. Water quality.**

A. Compliance with the water quality criteria may be achieved by applying the performance-based criteria or the technology-based criteria to either the site or a planning area.

B. Performance-based criteria. For land development, the calculated post-development nonpoint source pollutant runoff load shall be compared to the calculated pre-development load based upon the average land cover condition or the existing site condition. A BMP shall be located, designed, and maintained to achieve the target pollutant removal efficiencies specified in Table 1 to effectively reduce the pollutant load to the required level based upon the following four applicable land development situations for which the performance criteria apply:

1. Situation 1 consists of land development where the existing percent impervious cover is less than or equal to the average land cover condition and the proposed improvements will create a total percent impervious cover which is less than the average land cover condition.

Requirement: No reduction in the after development pollutant discharge is required.

2. Situation 2 consists of land development where the existing percent impervious cover is less than or equal to the average land cover condition and the proposed improvements will create a total percent impervious cover which is greater than the average land cover condition.

Requirement: The pollutant discharge after development shall not exceed the existing pollutant discharge based on the average land cover condition.

3. Situation 3 consists of land development where the existing percent impervious cover is greater than the average land cover condition.

Requirement: The pollutant discharge after development shall not exceed (i) the pollutant discharge based on existing conditions less 10% or (ii) the pollutant discharge based on the average land cover condition, whichever is greater.

4. Situation 4 consists of land development where the existing percent impervious cover is served by an existing stormwater management BMP that addresses water quality.

Requirement: The pollutant discharge after development shall not exceed the existing pollutant discharge based on the existing percent impervious cover while served by the existing BMP. The existing BMP shall be shown to have been designed and constructed in accordance with proper design standards and specifications, and to be in proper functioning condition.

C. Technology-based criteria. For land development, the post-developed stormwater runoff from the impervious cover shall be treated by an appropriate BMP as required by the post-developed condition percent impervious cover as specified in Table 1. The selected BMP shall be located, designed, and maintained to perform at the target pollutant removal efficiency specified in Table 1. Design standards and specifications for the BMPs in Table 1 which meet the required target pollutant removal efficiencywill be available at the department.

Table 1*

| Water Quality BMP | Target Phosphorus Removal Efficiency | Percent Impervious Cover |
|---|---|---|
| Vegetated filter strip | 10% | 16-21% |
| Grassed swale | 15% | |
| Constructed wetlands | 30% | 22 -37% |
| Extended detention (2 x WQ Vol) | 35% | |
| Retention basin I (3 x WQ Vol) | 40% | |
| Bioretention basin | 50% | 38 -66% |
| Bioretention filter | 50% | |
| Extended detention-enhanced | 50% | |
| Retention basin II (4 x WQ Vol) | 50% | |
| Infiltration (1 x WQ Vol) | 50% | |
| Sand filter | 65% | 67 -100% |
| Infiltration (2 x WQ Vol) | 65% | |
| Retention basin III (4 x WQ Vol with aquatic bench) | 65% | |

* Innovative or alternate BMPs not included in this table may be allowed at the discretion of the local program administrator or the Department. Innovative or alternate BMPs not included in this table which target appropriate nonpoint source pollution other than phosphorous may be allowed at the discretion of the local program administrator or the Department.

**4 VAC 3-20-81. Stream channel erosion.**

A. Properties and receiving waterways downstream of any land development project shall be protected from erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff in accordance with the minimum design standards set out in this section.

B. The plan approving authority shall require compliance with subdivision 19 of 4 VAC 50-30-40 of the Erosion and Sediment Control Regulations, promulgated pursuant to Article 4 (§ 10.1-560 et seq.) of Chapter 5 of Title 10.1 of the Code of Virginia.

C. The plan approving authority may determine that some watersheds or receiving stream systems require enhanced criteria in order to address the increased frequency of bankfull flow conditions brought on by land development projects. Therefore, in lieu of the reduction of the 2-year post-developed peak rate of runoff as required in subsection B of this section, the land development project being considered shall provide 24-hour extended detention of the runoff generated by the 1-year, 24-hour duration storm.

D. In addition to subsections B and C of this section, localities may, by ordinance, adopt more stringent channel analysis criteria or design standards to ensure that the natural level of channel erosion, to the maximum extent practicable, will not increase due to the land development projects. These criteria may include, but are not limited to, the following:

1. Criteria and procedures for channel analysis and classification.
2. Procedures for channel data collection.
3. Criteria and procedures for the determination of the magnitude and frequency of natural sediment transport loads.
4. Criteria for the selection of proposed natural or man-made channel linings.

**4 VAC 3-20-85. Flooding.**

A. Downstream properties and waterways shall be protected from damages from localized flooding due to increases in volume, velocity and peak flow rate of stormwater runoff in accordance with the minimum design standards set out in this section

B. The 10-year post-developed peak rate of runoff from the development site shall not exceed the 10-year pre-developed peak rate of runoff.

C. In lieu of subsection B of this section, localities may, by ordinance, adopt alternate design criteria based upon geographic, land use, topographic, geologic factors or other downstream conveyance factors as appropriate.

D. Linear development projects shall not be required to control post-developed stormwater runoff for flooding, except in accordance with a watershed or regional stormwater management plan.

**4 VAC 3-20-86. Regional (watershed-wide) stormwater management plans.**

This section enables localities to develop regional stormwater management plans. State agencies intending to develop large tracts of land such as campuses or prison compounds are encouraged to develop regional plans where practical.

The objective of a regional stormwater management plan is to address the stormwater management concerns in a given watershed with greater economy and efficiency by installing regional stormwater management facilities versus individual, site-specific facilities. The result will be fewer stormwater management facilities to design, build and maintain in the affected watershed. It is also anticipated that regional stormwater management facilities will not only help mitigate the impacts of new development, but may also provide for the remediation of erosion, flooding or water quality problems caused by existing development within the given watershed.

If developed, a regional plan shall, at a minimum, address the following:

1. The specific stormwater management issues within the targeted watersheds.

2. The technical criteria in 4 VAC 3-20-50 through 4 VAC 3-20-85 as needed based on subdivision 1 of this section.

3. The implications of any local comprehensive plans, zoning requirements and other planning documents.

4. Opportunities for financing a watershed plan through cost sharing with neighboring agencies or localities, implementation of regional stormwater utility fees, etc.

5. Maintenance of the selected stormwater management facilities.

6. Future expansion of the selected stormwater management facilities in the event that development exceeds the anticipated level.

## PART III.
## LOCAL PROGRAMS.

**4 VAC 3-20-90. Applicability.**

This part specifies technical criteria, minimum ordinance requirements, and administrative procedures for all localities operating local stormwater management programs.

**4 VAC 3-20-101. Technical criteria for local programs.**

A. All local stormwater management programs shall comply with the general technical criteria as outlined in 4 VAC 3-20-60.

B. All local stormwater management programs which contain provisions for stormwater runoff quality shall comply with 4 VAC 3-20-71. A locality may establish criteria for selecting either the site or a planning area on which to apply the water quality criteria. A locality may opt to calculate actual watershed specific or locality wide values for the average land cover condition based upon:

1. Existing land use data at time of local Chesapeake Bay Preservation Act Program or Department storm water management program adoption, whichever was adopted first,

2. Watershed or locality size, and

3. Determination of equivalent values of impervious cover for nonurban land uses which contribute nonpoint source pollution, such as agriculture, forest, etc.

C. All local stormwater management programs which contain provisions for stream channel erosion shall comply with 4 VAC 3-20-81.

D. All local stormwater management programs must contain provisions for flooding and shall comply with 4 VAC 3-20-85.

E. All local stormwater management programs which contain provisions for watershed or regional stormwater management plans shall comply with 4 VAC 3-20-101.

F. A locality that has adopted more stringent requirements or implemented a regional (watershed-wide) stormwater management plan may request, in writing, that the department consider these requirements in its review of state projects within that locality.

G. Nothing in this part shall be construed as authorizing a locality to regulate, or to require prior approval by the locality for, a state project.

**4 VAC 3-20-111. Requirements for local program and ordinance.**

A. At a minimum, the local stormwater management program and implementing ordinance shall meet the following:

1. The ordinance shall identify the plan-approving authority and other positions of authority within the program, and shall include the regulations and technical criteria to be used in the program.

2. The ordinance shall include procedures for submission and approval of plans, issuance of permits, monitoring and inspections of land development projects. The party responsible for conducting inspections shall be identified. The local program authority shall maintain, either on-site or in local program files, a copy of the approved plan and a record of all inspections for each land development project.

B. The department shall periodically review each locality's stormwater management program, implementing ordinance, and amendments. Subsequent to this review, the department shall determine if the program and ordinance are consistent with the state stormwater management regulations and notify the locality of its findings. To the maximum extent practicable the department will coordinate the reviews with other local government program reviews to avoid redundancy. The review of a local program shall consist of the following:

1. A personal interview between department staff and the local program administrator or his designee;

2. A review of the local ordinance and other applicable documents;

3. A review of plans approved by the locality and consistency of application;

4. An inspection of regulated activities; and

5. A review of enforcement actions.

C. Nothing in this chapter shall be construed as limiting the rights of other federal and state agencies from imposing stricter technical criteria or other requirements as allowed by law.

**4 VAC 3-20-121. Administrative procedures: stormwater management plans.**

A. Localities shall approve or disapprove stormwater management plans according to the following:

1. A maximum of 60 calendar days from the day a complete stormwater management plan is accepted for review will be allowed for the review of the plan. During the 60-day review period, the locality shall either approve or disapprove the plan and communicate its decision to the applicant in writing. Approval or denial shall be based on the plan's compliance with the locality's stormwater management program.

2. A disapproval of a plan shall contain the reasons for disapproval.

B. Each plan approved by a locality shall be subject to the following conditions:

1. The applicant shall comply with all applicable requirements of the approved plan, the local program, this chapter and the Act, and shall certify that all land clearing, construction, land development and drainage will be done according to the approved plan.

2. The land development project shall be conducted only within the area specified in the approved plan.

3. The locality shall be allowed, after giving notice to the owner, occupier or operator of the land development project, to conduct periodic inspections of the project.

4. The person responsible for implementing the approved plan shall conduct monitoring and submit reports as the locality may require to ensure compliance with the approved plan and to determine whether the plan provides effective stormwater management.

5. No changes may be made to an approved plan without review and written approval by the locality.

**4 VAC 3-20-131. Administrative procedures: exceptions.**

A. A request for an exception shall be submitted, in writing, to the locality. An exception from the stormwater management regulations may be granted, provided that: (i) exceptions to the criteria are the minimum necessary to afford relief and (ii) reasonable and appropriate conditions shall be imposed as necessary upon any exception granted so that the intent of the Act and this chapter are preserved.

B. Economic hardship is not sufficient reason to grant an exception from the requirements of this chapter.

**4 VAC 3-20-141. Administrative procedures: maintenance and inspections.**

A. Responsibility for the operation and maintenance of stormwater management facilities, unless assumed by a governmental agency, shall remain with the property owner and shall pass to any successor or owner. If portions of the land are to be sold, legally binding arrangements shall be made to pass the basic responsibility to successors in title. These arrangements shall designate for each project the property owner, governmental agency, or other legally established entity to be permanently responsible for maintenance.

B. In the case of developments where lots are to be sold, permanent arrangements satisfactory to the locality shall be made to ensure continued performance of this chapter.

C. A schedule of maintenance inspections shall be incorporated into the local ordinance. Ordinances shall provide that in cases where maintenance or repair is neglected, or the stormwater management facility becomes a danger to public health or safety, the locality has the authority to perform the work and to recover the costs from the owner.

D. Localities may require right-of-entry agreements or easements from the applicant for purposes of inspection and maintenance.

E. Periodic inspections are required for all stormwater management facilities. Localities shall either:

1. Provide for inspection of stormwater management facilities on an annual basis; or

2. Establish an alternative inspection program which ensures that stormwater management facilities are functioning as intended. Any alternative inspection program shall be:

   a. Established in writing;

   b. Based on a system of priorities that, at a minimum, considers the purpose of the facility, the contributing drainage area, and downstream conditions; and

   c. Documented by inspection records.

F. During construction of the stormwater management facilities, localities shall make inspections on a regular basis.

G. Inspection reports shall be maintained as part of a land development project file.

PART IV.
STATE PROJECTS.

**4 VAC 3-20-210. Technical criteria and plan requirements for state projects.**

A. This part specifies technical criteria and administrative procedures for all state projects.

B. Stormwater management plans prepared for state projects shall comply with the technical criteria outlined in Part II (4 VAC 3-20-50 et seq.) of this chapter and, to the maximum extent practicable, any local stormwater management program technical requirements adopted pursuant to the Act. It shall be the responsibility of the state agency to demonstrate that the local program technical requirements are not practical for the project under consideration.

C. The department may establish criteria for selecting either the site or a planning area on which to apply the water quality criteria.

D. As a minimum, stormwater management plans and computations shall contain the following:

1. The location and the design of the proposed stormwater management facilities.

2. Overall site plan with pre-developed and post-developed condition drainage area maps.

3. Comprehensive hydrologic and hydraulic computations of the pre-development and post-development runoff conditions for the required design storms, considered individually.

4. Calculations verifying compliance with the water quality requirements.

5. A description of the requirements for maintenance of the stormwater management facilities and a recommended schedule of inspection and maintenance.

6. The identification of a person or persons who will be responsible for maintenance.

7. All stormwater management plans shall be appropriately sealed and signed by a professional in adherence to all minimum standards and requirements pertaining to the practice of that profession in accordance with Chapter 4 (§ 54.1-400 et seq.) of Title 54.1 of the Code of Virginia and attendant regulations.

**4 VAC 3-20-220. Requirements for stormwater management annual standards and specifications.**

A. A request for approval of stormwater management standards and specifications may be submitted to the department by a state agency on an annual basis. At a minimum, the following certifications shall accompany the request:

1. Individual stormwater management plans shall be prepared for each of the state projects.

2. The stormwater management plans shall comply with the technical criteria as outlined in Part II (4 VAC 3-20-50 et seq.) of this chapter and, to the maximum extent practicable, any local stormwater management program technical requirements adopted pursuant to the Stormwater Management Act. It shall be the responsibility of the state agency to demonstrate that the local program technical requirements are not practical for the project under consideration.

3. An inspection and maintenance schedule shall be developed and implemented.

B. Copies of such stormwater management specifications and standards including, but not limited to, design manuals, technical guides and handbooks, shall be submitted.

**4 VAC 3-20-230. Administrative procedures: stormwater management plans.**

A. Within 30 days after receipt of a complete stormwater management plan submitted by a state agency, the department shall approve or disapprove the plan.

1. The department shall transmit its decision in writing to the state agency which submitted the plan.

2. Disapproved plans shall be revised and resubmitted to the department.

B. Approval of a stormwater management plan for a state project shall be subject to the following conditions:

1. The state agency shall comply with all applicable requirements of the approved plan and this chapter, and shall certify that all land clearing, construction, land development, and drainage will be done according to the approved plan.

2. The land development shall be conducted only within the area specified in the approved plan.

3. No changes may be made to an approved plan without review and written approval by the department.

4. The department shall be notified one week prior to the pre-construction meeting and one week prior to the commencement of land disturbing activity.

5. The department shall conduct periodic inspections of the project to ensure compliance with the plan.

6. The department may require monitoring and reports from the state agency responsible for implementing the plan to ensure compliance with the plan and to determine if the measures required in the plan provide effective stormwater management.

C. Compliance with approved plans shall be subject to the following conditions:

1. Where inspections by department personnel reveal deficiencies in carrying out an approved plan, the responsible state agency shall be issued a notice to comply, with corrective actions specified and the deadline within which the work shall be performed.

2. Whenever the Commonwealth or any of its agencies fail to comply within the time provided in a notice to comply, the director may petition the secretary of a given secretariat or an agency head for a given state agency for compliance. Where the petition does not achieve timely compliance, the director shall bring the matter to the Governor for resolution.

3. Where compliance will require the appropriation of funds, the director shall cooperate with the appropriate agency head in seeking such an appropriation; where the director determines that an emergency exists, he shall petition the Governor for funds from the Civil Contingency Fund or other appropriate source.

**4 VAC 3-20-241. Administrative procedures: exceptions.**

A. A request for an exception shall be submitted, in writing, to the department. An exception from the stormwater management regulations may be granted, provided that: (i) exceptions to the criteria are the minimum necessary to afford relief and (ii) reasonable and appropriate conditions shall be imposed as necessary upon any exception granted so that the purpose and intent of the Act is preserved.

B. Economic hardship is not sufficient reason to grant an exception from the requirements of this chapter.

**4 VAC 3-20-245. Administrative procedures: maintenance and inspections.**

A. Responsibility for the operation and maintenance of stormwater management facilities shall remain with the state agency and shall pass to any successor or owner. If portions of the land are to be sold, legally binding arrangements shall be made to pass the basic responsibility to successors in title. These arrangements shall designate for each state project the property owner, governmental agency, or other legally established entity to be permanently responsible for maintenance.

B. At a minimum, a stormwater management facility shall be inspected on an annual basis and after any storm which causes the capacity of the facility principal spillway to be exceeded.

C. During construction of the stormwater management facilities, the department shall make inspections on a regular basis.

D. Inspection reports shall be maintained as part of the land development project file.

PART V.
REPORTING.

**4 VAC 3-20-251. Reporting on stormwater management.**

The department is required to report to the General Assembly on the extent to which stormwater management programs have reduced nonpoint source pollution to the Commonwealth's waters and mitigated the effects of localized flooding. In order to complete this report, localities with stormwater management programs and state agencies may be asked to voluntarily submit an annual report to the department. Such a request may suggest reporting of data on the number and types of stormwater management facilities installed in the preceding year, the drainage area or watershed size served, the receiving stream or hydrologic unit, a summary of monitoring data, if any, and other data useful in determining the effectiveness of the programs and BMP technologies in current use.

## 1-5 VIRGINIA EROSION AND SEDIMENT CONTROL REGULATIONS

The following is a complete text of the Virginia Erosion and Sediment Control Regulations 4VAC50-30 amended by the Virginia Soil and Water Conservation Board, Effective March 22, 1995

**§4VAC50-30-10 <u>Definitions.</u>**

The following words and terms, when used in these regulations, shall have the following meaning, unless the context clearly indicates otherwise. In addition, some terms not defined herein are defined in §10.1-560 of the Erosion and Sediment Control Law.

*"Act"* means the Erosion and Sediment Control Law, Article 4 (§10.1-560 et seq.) of Chapter 5 of Title 10.1 of the Code of Virginia.

"*Adequate channel*" means a watercourse that will convey the designated frequency storm event without overtopping its banks or causing erosive damage to the bed, banks and overbank sections of the same.

"*Agreement in lieu of a plan*" means a contract between the program authority and the owner which specifies conservation measures which must be implemented in the construction of a single-family residence; this contract may be executed by the program authority in lieu of an erosion and sediment control plan.

"*Applicant*" means any person submitting an erosion and sediment control plan or an agreement in lieu of a plan for approval or requesting the issuance of a permit, when required, authorizing land-disturbing activities to commence.

"*Board*" means the Virginia Soil and Water Conservation Board.

"*Causeway*" means a temporary structural span constructed across a flowing watercourse or wetland to allow construction traffic to access the area without causing erosion damage.

"*Channel*" means a natural stream or manmade waterway.

"*Cofferdam*" means a watertight temporary structure in a river, lake, etc., for keeping the water from an enclosed area that has been pumped dry so that bridge foundations, dams, etc., may be constructed.

"*Dam*" means a barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or to retain soil, rock or other debris.

"*Denuded*" means a term applied to land that has been physically disturbed and no longer supports vegetative cover.

"*Department*" means the Department of Conservation and Recreation.

"*Development*" means a tract or parcel of land developed or to be developed as a single unit under single ownership or unified control which is to be used for any business or industrial purpose or is to contain three or more residential dwelling units.

"*Dike*" means an earthen embankment constructed to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; levee.

"*Director*" means the Director of the Department of Conservation and Recreation.

"*District*" or "soil and water conservation district" means a political subdivision of the Commonwealth organized in accordance with the provisions of Article 3 (§10.1-506 et seq.) of Chapter 5 of Title 10.1 of the Code of Virginia.

"*Diversion*" means a channel with a supporting earthen ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

"*Dormant*" refers to denuded land that is not actively being brought to a desired grade or condition.

"*Energy dissipator*" means a non-erodible structure which reduces the velocity of concentrated flow to reduce its erosive effects.

"*Erosion and* sediment control plan, *conservation plan*" or "*plan*," means a document containing material for the conservation of soil and water resources of a unit or group of units of land. It may include appropriate maps, an appropriate soil and water plan inventory and management information with needed interpretations, and a record of decisions contributing to conservation treatment. The plan shall contain all major conservation decisions and all information deemed necessary by the plan-approving authority to assure that the entire unit or units of land will be so treated to achieve the conservation objectives.

"*Flume*" means a constructed device lined with erosion-resistant materials intended to convey water on steep grades.

"*Hydraulic outlet structure*" means a control section composed of orifice(s), weir(s) and/or conduit(s) which release impounded runoff at a prescribed flowrate.

"*Hydrologic unit*" means a defined land area drained by a river/stream or system of connecting rivers/streams such that all surface water within the area flows through a single outlet.

"*Live watercourse*" means a definite channel with bed and banks within which concentrated water flows continuously.

"*Locality*" means a county, city or town.

"*Natural stream*" means nontidal waterways that are part of the natural topography. They usually maintain a continuous or seasonal flow during the year and are characterized as being irregular in cross-section with a meandering course. Constructed channels such as drainage ditches or swales shall not be considered natural streams.

"*Nonerodible*" means a material, e.g., riprap, concrete, plastic, etc., that will not experience surface wear due to natural forces.

"*Person*" means any individual, partnership, firm, association, joint venture, public or private corporation, trust, estate, commission, board, public or private institution, utility, cooperative, county, city, town or other political subdivision of the Commonwealth, any interstate body, or any other legal entity.

"*Plan-approving authority*" means the Board, the program authority a department of a program authority, or an agent of the program authority responsible for determining the adequacy of a conservation plan submitted for land-disturbing activities on a unit or units of land and for approving plans.

"*Post-development*" refers to conditions that may be reasonably expected or anticipated to exist after completion of the land development activity on a specific site or tract of land.

"*Program administrator*" means the person or persons responsible for administering and enforcing the erosion and sediment control program of a program authority.

*"Program authority"* means a district, county, city, or town which has adopted a soil erosion and sediment control program which has been approved by the Board.

"*Pre-development*" refers to conditions at the time the erosion and sediment control plan is submitted to the plan-approving authority. Where phased development or plan approval occurs (preliminary grading, roads and utilities, etc.), the existing conditions at the time the erosion and sediment control plan for the initial phase is submitted for approval shall establish pre-development conditions.

"*Sediment basin*" means a temporary impoundment built to retain sediment and debris with a controlled stormwater release structure.

"*Sediment trap*" means a temporary impoundment built to retain sediment and debris which is formed by constructing an earthen embankment with a stone outlet.

"*Sheet flow*" (also called overland flow) means shallow, unconcentrated and irregular flow down a slope. The length of strip for overland flow usually does not exceed 200 feet under natural conditions.

*Shore erosion control project*" means an erosion control project approved by local wetlands boards, the Virginia Marine Resources Commission, the Virginia Department of Environmental Quality or the United States Army Corps of Engineers and located on tidal waters and within nonvegetated or vegetated wetlands as defined in Title 28.2 of the Code of Virginia.

"*Slope drain*" means tubing or conduit made of nonerosive material extending from the top to the bottom of a cut or fill slope with an energy dissipator at the outlet end.

"*Stabilized*" means land that has been treated to withstand normal exposure to natural forces without incurring erosion damage.

"*Storm sewer inlet*" means a structure through which stormwater is introduced into an underground conveyance system.

"*Stormwater detention*" means the process of temporarily impounding runoff and discharging it through a hydraulic outlet structure to a downstream conveyance system.

"*Temporary vehicular stream crossing*" means a temporary nonerodible structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes or pipe arches constructed on or through nonerodible material.

"*Ten-year storm*" means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in 10 years. It may also be expressed as an exceedence probability with a 10% chance of being equaled or exceeded in any given year.

*"Two-year storm*" means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in two years. It may also be expressed as an exceedence probability with a 50% chance of being equaled or exceeded in any given year.

*"Twenty-five-year storm"* means a storm that is capable of producing rainfall expected to be equaled or exceeded on the average of once in twenty-five years. It may also be expressed as exceedence probability with a 4% chance of being equaled or exceeded in any given year.

**§4VAC50-30-20 Purpose.**

The purpose of these regulations is to form the basis for the administration, implementation and enforcement of the Act. The intent of these regulations is to establish the framework for compliance with the Act while at the same time providing flexibility for innovative solutions to erosion and sediment control concerns.

**§4VAC50-30-30 Scope and Applicability.**

A. These regulations set forth minimum standards for the effective control of soil erosion, sediment deposition and nonagricultural runoff that must be met:

    1. In erosion and sediment control programs adopted by districts and localities under §10.1-562 of the Act.

    2. In erosion and sediment control plans that may be submitted directly to the Board pursuant to §10.1-563 A of the Act;

3. In annual general erosion and sediment control specifications that electric and telephone utility companies and railroad companies are required to file with the Board pursuant to §10.1-563 D of the Act;

4. In conservation plans and annual specifications that state agencies are required to file with the Department pursuant to §10.1-564 of the Act; and

5. By federal agencies that enter into agreements with the Board.

B. The submission of annual specifications to the Board or the Department by any agency or company does not eliminate the need for a project specific erosion and sediment control plan.

C. These regulations must be incorporated into the local erosion and sediment control program within one year of their effective date.

**§4VAC50-30-40 Minimum Standards.**

An erosion and sediment control program adopted by a district or locality must be consistent with the following criteria, techniques and methods:

1. Permanent or temporary soil stabilization shall be applied to denuded areas within seven days after final grade is reached on any portion of the site. Temporary soil stabilization shall be applied within seven days to denuded areas that may not be at final grade but will remain dormant for longer than 30 days. Permanent stabilization shall be applied to areas that are to be left dormant for more than one year.

2. During construction of the project, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures. The applicant is responsible for the temporary protection and permanent stabilization of all soil stockpiles on site as well as borrow areas and soil intentionally transported from the project site.

3. A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized. Permanent vegetation shall not be considered established until a ground cover is achieved that, is uniform, mature enough to survive and will inhibit erosion.

4. Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

5. Stabilization measures shall be applied to earthen structures such as dams, dikes and diversions immediately after installation.

6. Sediment traps and sediment basins shall be designed and constructed based upon the

total drainage area to be served by the trap or basin.

a. The minimum storage capacity of a sediment trap shall be 134 cubic yards per acre of drainage area and the trap shall only control drainage areas less than three acres.

b. Surface runoff from disturbed areas that is comprised of flow from drainage areas greater than or equal to three acres shall be controlled by a sediment basin. The minimum storage capacity of a sediment basin shall be 134 cubic yards per acre of drainage area. The outfall system shall, at a minimum, maintain the structural integrity of the basin during a twenty-five year storm of 24-hour duration. Runoff coefficients used in runoff calculations shall correspond to a bare earth condition or those conditions expected to exist while the sediment basin is utilized.

7. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

8. Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.

9. Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

10. All storm sewer inlets that are made operable during construction shall be protected so that sediment-laden water cannot enter the conveyance system without first being filtered or otherwise treated to remove sediment.

11. Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and receiving channel.

12. When work in a live watercourse is performed, precautions shall be taken to minimize encroachment, control sediment transport and stabilize the work area to the greatest extent possible during construction. Nonerodible material shall be used for the construction of causeways and cofferdams. Earthen fill may be used for these structures if armored by nonerodible cover materials.

13. When a live watercourse must be crossed by construction vehicles more than twice in any six-month period, a temporary vehicular stream crossing constructed of nonerodible material shall be provided.

14. All applicable federal, state and local regulations pertaining to working in or crossing live watercourses shall be met.

15. The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse is completed.

16. Underground utility lines shall be installed in accordance with the following standards in addition to other applicable criteria:

    a. No more than 500 linear feet of trench may be opened at one time.

    b. Excavated material shall be placed on the uphill side of trenches.

    c. Effluent from dewatering operations shall be filtered or passed through an approved sediment trapping device, or both, and discharged in a manner that does not adversely affect flowing streams or off-site property.

    d. Material used for backfilling trenches shall be properly compacted in order to minimize erosion and promote stabilization.

    e. Restabilization shall be accomplished in accordance with these regulations.

    f. Applicable safety regulations shall be complied with.

17. Where construction vehicle access routes intersect paved or public roads, provisions shall be made to minimize the transport of sediment by vehicular tracking onto the paved surface. Where sediment is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly at the end of each day. Sediment shall be removed from the roads by shoveling or sweeping and transported to a sediment control disposal area. Street washing shall be allowed only after sediment is removed in this manner. This provision shall apply to individual development lots as well as to larger land-disturbing activities.

18. All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed, unless otherwise authorized by the local program authority. Trapped sediment and the disturbed soil areas resulting from the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.

19. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff for the stated frequency storm of 24-hour duration in accordance with the following standards and criteria:

    a. Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.

b. Adequacy of all channels and pipes shall be verified in the following manner:

(1) The applicant shall demonstrate that the total drainage area to the point of analysis within the channel is one hundred times greater than the contributing drainage area of the project in question; or

(2) (a) Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks; and

(b) All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and

(c) Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system.

c. If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall:

(1) Improve the channel to a condition where a ten-year storm will not overtop the banks and a two-year storm will not cause erosion to the channel bed or banks; or

(2) Improve the pipe or pipe system to a condition where the ten-year storm is contained within the appurtenances; or

(3) Develop a site design that will not cause the pre-development peak runoff rate from a two-year storm to increase when runoff outfalls into a natural channel or will not cause the pre-development peak runoff rate from a ten-year storm to increase when runoff outfalls into a man-made channel; or

(4) Provide a combination of channel improvement, stormwater detention or other measures which is satisfactory to the plan-approving authority to prevent downstream erosion.

d. The applicant shall provide evidence of permission to make the improvements.

e. All hydrologic analyses shall be based on the existing watershed characteristics and the ultimate development of the subject project.

f. If the applicant chooses an option that includes stormwater detention he shall obtain approval from the locality of a plan for maintenance of the detention facilities. The plan shall set forth the maintenance requirements of the facility and the person responsible for performing the maintenance.

g. Outfall from a detention facility shall be discharged to a receiving channel, and energy dissipators shall be placed at the outfall of all detention facilities as necessary to provide a stabilized transition from the facility to the receiving channel.

h. All on-site channels must be verified to be adequate.

I. Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility.

j. In applying these stormwater runoff criteria, individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development, as a whole, shall be considered to be a single development project. Hydrologic parameters that reflect the ultimate development condition shall be used in all engineering calculations.

k. All measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state.

**§4VAC50-30-50 Variances.**

The plan-approving authority may waive or modify any of the regulations that are deemed inappropriate or too restrictive for site conditions, by granting a variance. A variance may be granted under these conditions:

1. At the time of plan submission, an applicant may request a variance to become part of the approved erosion and sediment control plan. The applicant shall explain the reasons for requesting variances in writing. Specific variances which are allowed by the plan-approving authority shall be documented in the plan.

2. During construction, the person responsible for implementing the approved plan may request a variance in writing from the plan-approving authority.
The plan-approving authority shall respond in writing either approving or disapproving such a request. If the plan-approving authority does not approve a variance within 10 days of receipt of the request, the request shall be considered to be disapproved. Following disapproval, the applicant may resubmit a variance request with additional documentation.

3. The plan-approving authority shall consider variance requests judiciously, keeping in

mind both the need of the applicant to maximize cost effectiveness and the need to protect off-site properties and resources from damage.

**§4VAC50-30-60 Maintenance and Inspections.**

A. All erosion and sediment control structures and systems shall be maintained, inspected and repaired as needed to insure continued performance of their intended function. A statement describing the maintenance responsibilities of the permittee shall be included in the approved erosion and sediment control plan.

B. Periodic inspections are required on all projects by the program authority. The program authority shall either:

a. provide for an inspection during or immediately following initial installation of erosion and sediment controls, at least once in every two-week period, within 48 hours following any runoff producing storm event, and at the completion of the project prior to the release of any performance bonds; or

b. Establish an alternative inspection program which ensures compliance with the approved erosion and sediment control plan. Any alternative inspection program shall be:

(1) Approved by the Board prior to implementation;

(2) Established in writing;

(3) Based upon a system of priorities that, at a minimum, address the amount of disturbed project area, site conditions and stage of construction; and
(4) Documented by inspection records.

**§4VAC50-30-70 Developments.**

A. An erosion and sediment control plan shall be filed for a development and the buildings constructed within, regardless of the phasing of construction.

B. If individual lots or sections in a residential development are being developed by different property owners, all land-disturbing activities related to the building construction shall be covered by an erosion and sediment control plan or an "Agreement in Lieu of a Plan" signed by the property owner.

C. Land-disturbing activity of less than 10,000 square feet on individual lots in a residential development shall not be considered exempt from the provisions of the act and these regulations if the total land-disturbing activity in the development is equal to or greater than 10,000 square feet.

**§4VAC50-30-80 Criteria for Determining Status of Land-disturbing Activity.**

A. The program administrator shall determine the validity of a claim of exempt status by a property owner who disturbs 10,000 square feet or more. As soon as a nonexempt status is determined, the requirements of the Act shall be immediately enforced.

B. Should a land-disturbing activity not begin during the 180-day period following plan approval or cease for more than 180 days, the plan-approval authority or the permit-issuing authority may evaluate the existing approved erosion and sediment control plan to determine whether the plan still satisfies local and state erosion and sediment control criteria and to verify that all design factors are still valid. If the authority finds the previously filed plan to be inadequate, a modified plan shall be submitted and approved prior to the resumption of land-disturbing activity.

C. Shore erosion control projects are not subject to these regulations. However, land-disturbing activity immediately outside the limits of the shore erosion project is subject to the Act and these regulations.

D. Whenever land-disturbing activity involves activity at a separate location (including but not limited to borrow and disposal areas), the program authority may either:

1. Consider the off-site activity as being part of the proposed land-disturbing activity; or,

2. If the off-site activity is already covered by an approved erosion and sediment control plan, the program authority may require the applicant to provide proof of the approval and to certify that the plan will be implemented in accordance with the Act and these regulations.

**§4VAC50-30-90 Review and Evaluation of Local Programs: Minimum Program Standards**

A. This section sets forth the criteria that will be used by the Department to determine whether a local program operating under authority of the Act, satisfies minimum standards of effectiveness, as follows.

Each local program must contain an ordinance or other appropriate document(s) adopted by the governing body. Such document(s) must be consistent with the Act and 4VAC50-30 and 4VAC50-50, including the following criteria:

1. The document(s) shall include or reference the definition of land-disturbing activity including exemptions, as well as any other significant terms, as necessary to produce an effective local program.

2. The document(s) shall identify the plan-approving authority and other positions of authority within the program, and must include the regulations and design standards to be used in the program.

3. The document(s) shall include procedures for submission and approval of plans, issuance of permits, monitoring and inspections of land-disturbing activities. The position, agency, department, or other party responsible for conducting inspections shall be identified. The local program authority shall maintain, either on-site or in local program files, a copy of the approved plan and a record of inspections for each active land-disturbing activity.

4. The local program authority must take appropriate enforcement actions to achieve compliance with the program and maintain a record of enforcement actions for all active land-disturbing activities.

B. The Department staff, under authority of the Board, shall periodically conduct a comprehensive review and evaluation of local programs. The review of a local program shall consist of the following: (1) personal interview between the Department staff and the local program administrator or designee(s); (2) review of the local ordinance and other applicable documents; (3) review of plans approved by the program; (4) inspection of regulated activities; (5) review of enforcement actions.

C. Local programs shall be reviewed and evaluated for effectiveness in carrying out the Act using the criteria in this section. However, the Director is not limited to the consideration of only these items when assessing the overall effectiveness of a local program.

D. If the Director determines that the deficiencies noted in the review will cause the local erosion and sediment control program to be inconsistent with the state program and regulations, the Director shall notify the local program authority concerning the deficiencies and provide a reasonable period of time for corrective action to be taken. If the program authority fails to take the corrective action within the specified time, the Director may formally request Board action pursuant to Code of Virginia §10.1-562.

E. Review and evaluation of local programs shall be conducted according to a schedule adopted by the Board.

**§4VAC50-30-100 State Agency Projects**

A. All state agency land-disturbing activities that are not exempt and that have commenced without an approved erosion and sediment control plan shall immediately cease until an erosion and sediment control plan has been submitted to and approved by the Department. A formal "Notice of Plan Requirement" will be sent to the state agency under whose purview the project lies since that agency is responsible for compliance with the Act.

B. Where inspections by Department personnel reveal deficiencies in carrying out an approved plan, the person responsible for carrying out the plan, as well as the state agency responsible, will be issued a notice to comply with specific actions and the deadlines that shall be met. Failure to meet the prescribed deadlines can result in the issuance of a stop work order for all land-disturbing activities on the project at the discretion of the Director of the Department or his designee who is authorized to sign such an order. The stop work order will be lifted once the required erosion and sediment control measures are in place and inspected by department staff.

C. Whenever the Commonwealth or any of its agencies fails to comply within the time provided in an appropriate final order, the Director of the Department may petition for compliance as follows: For violations in the Natural Resources Secretariat, to the Secretary of Natural Resources; for violations in other secretariats, to the appropriate secretary; for violations in other state agencies, to the head of such agency. Where the petition does not achieve timely compliance, the Director shall bring the matter to the Governor for resolution.

D. Where compliance will require the appropriation of funds, the Director shall cooperate with the appropriate agency head in seeking such an appropriation; where the Director determines that an emergency exists, he shall petition the Governor for funds from the Civil Contingency Fund or other appropriate source.

**§4VAC50-30-110 <u>Board Adopted Local Erosion and Sediment Control Programs</u>**

A. To carry out its duties under §10.1-562, the Board shall develop, adopt, and administer an appropriate local erosion and sediment control program for the locality under consideration. In fulfilling these duties, the Board shall assume the full powers of the local erosion and sediment control program granted by law.

B. The Board shall develop, adopt and administer a local erosion and sediment control program based on the minimum program standards established by these regulations and, as deemed appropriate by the Board, may include any or all of the provisions provided by law and regulations including administrative fees and performance securities.

C. Upon adoption of a local erosion and sediment control program by the Board, payment of monies including fees, securities, and penalties shall be made to the state treasury.

D. When administering a local erosion and sediment control program the Board may delegate to the Director such operational activities as necessary. Further, the Board may enter into agreements with other public or private entities to accomplish certain program responsibilities as it deems necessary to administer the local program.

# DCR-DSWC REGIONAL
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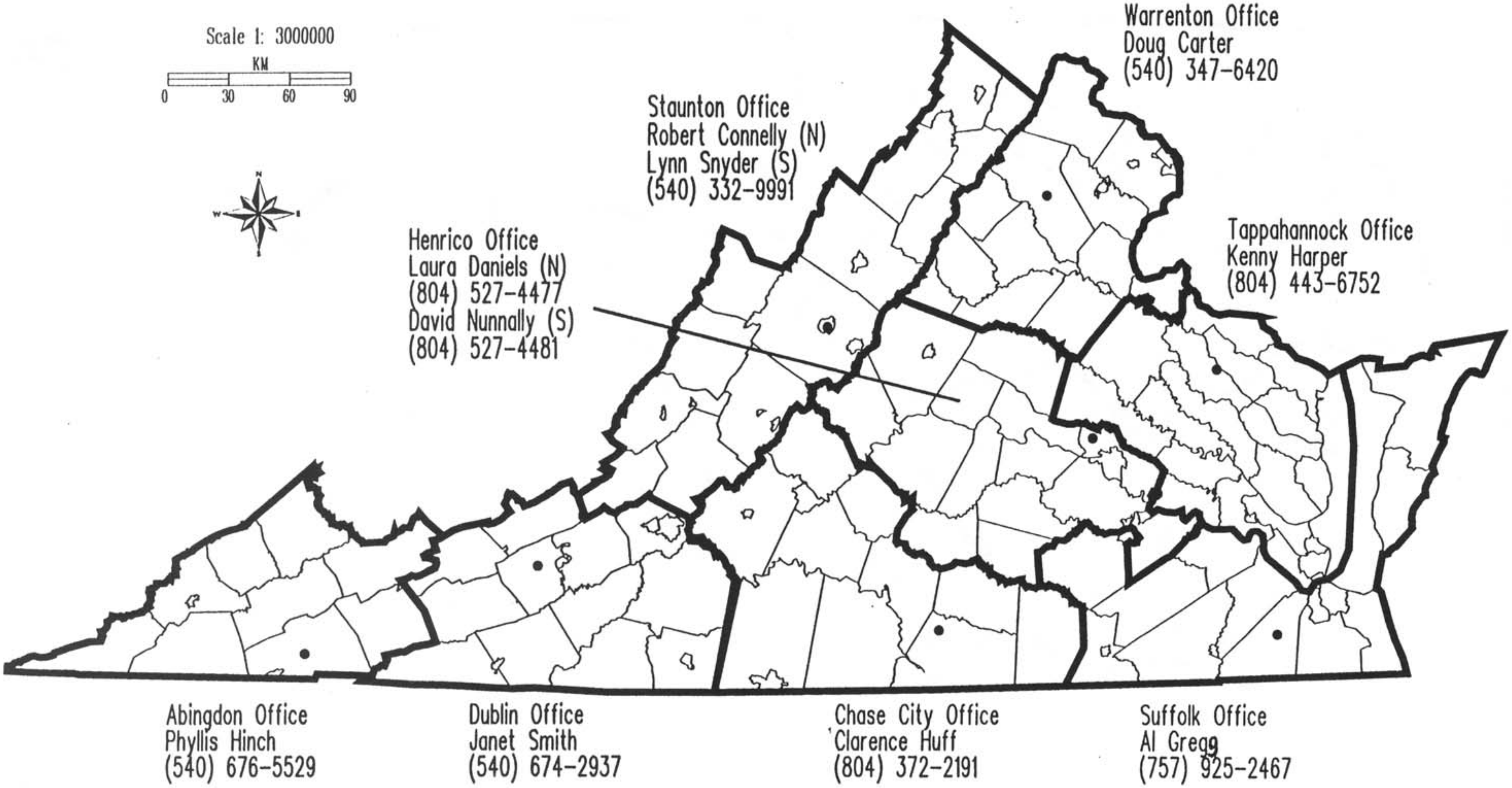


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# DCR-DSWC REGIONAL
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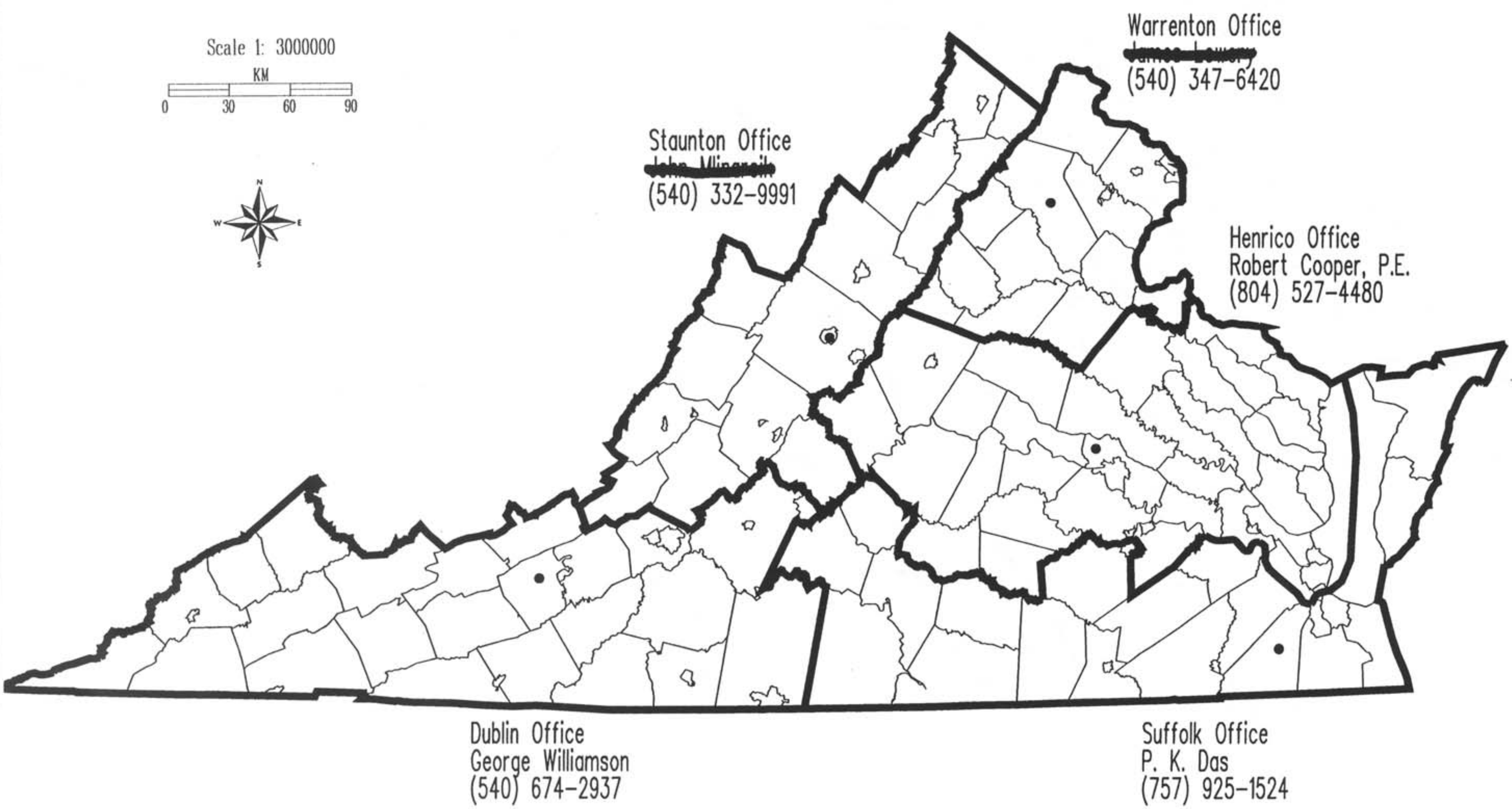


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# CHAPTER 2

## STORMWATER MANAGEMENT and URBAN BMPs

# TABLE OF CONTENTS

| # | SECTIONS | PAGE |
|---|---|---|



## LIST OF ILLUSTRATIONS

| # | FIGURES | PAGE |
|---|---|---|



| # | TABLES | PAGE |
|---|---|---|

## 2-1 COMPONENTS OF STORMWATER MANAGEMENT

The goal of storm water management is to mitigate the impact on the hydrologic cycle resulting from changes to the land surface. Urban development has been identified as having a direct impact on the hydrologic cycle by reducing or even eliminating the natural storage capacity of the land. This impact is the result of a decrease in tree cover, loose organic surface soils, and natural depressions, all of which provide natural storage capacity. These natural storage areas are then replaced with impervious and managed pervious surfaces. Impervious cover prevents the percolation of the runoff into the soil, which means that most, if not all of the rainfall is converted to runoff. In addition, managed pervious areas, such as courtyards and lawn areas typically do not provide opportunities for infiltration due to compaction of the surface soil profile and improved drainage conveyances. (The impact of development on the hydrologic cycle is discussed in detail in **Chapter 4; Hydrologic Methods**.) The results of increased stormwater runoff can be classified by its impact on *water quality*, *stream channel erosion*, and *localized flooding*. These components are identified in the Virginia Stormwater Management (SWM) Regulations.

### 2-1.1 Water Quality

One of the impacts of stormwater runoff is that of the quality of the runoff on the aquatic ecosystem. Various soluble and particulate pollutants are found in stormwater runoff. Studies have shown that the source of these pollutants are atmospheric deposition, urban and agricultural lands, and natural spaces. The focus of this document is on the urban land sources. The impervious surfaces, such as parking lots, roof tops, roads, etc., which are associated with land development serve to accumulate and transport these pollutants to receiving stream channels. It should be noted that pervious areas associated with development, such as golf courses, parks, open space, etc., also contribute pollutants.

The following presents a basic overview of the typical urban pollutants. Additional discussion of urban pollutants associated with certain ultra-urban development environments, referred to as *stormwater hotspots* (Claytor, 1996) is discussed in **Section 2-3: BMP Selection Criteria**.

*Nutrients.* Concentrations of nutrients, such as nitrogen and phosphorus, found in urban runoff can cause eutrophication of receiving streams, lakes, and rivers, and estuaries. As these nutrients collect in slower moving water bodies, they promote the growth of algae, which in turn blocks sunlight to bottom grasses, and eventually leads to a depletion of available dissolved oxygen (DO). Nutrients in urban runoff have been identified as being a significant contributor to the decline of the Chesapeake Bay. The Virginia Tributary Strategy initiative calls for a 40% reduction in nutrients reaching the Chesapeake Bay by the year 2000.

*Suspended solids.* All natural drainage channels have a natural sediment bed load which helps maintain a state of equilibrium within the channels of undeveloped watersheds. Increases in the peak rates of flow through the channel or stream system will disrupt the equilibrium by increasing the amount of sediment removed from the channel bed and banks. Suspended solids which result from excessive erosion and scour of the stream channel, the transport of sediments from impervious and managed pervious surfaces, and construction site runoff can have many adverse impacts on aquatic life throughout the water column. Further, these sediments will eventually settle in slower waters and smother the benthic habitat.

The "shock loading" which results from construction site runoff is most damaging to the aquatic habitat. The Virginia Erosion and Sediment Control Program addresses construction site runoff with the implementation of temporary erosion and sediment control measures specifically designed to inhibit sediment from leaving the site, as well as specifications for stabilization of the site once construction is complete. Even after final stabilization, however, loose soil or worn areas will continue to be a source of sediment to the receiving streams.

*Bacteria*. Varying levels of bacteria found in surface stormwater runoff can create public health concerns in receiving streams and lakes. The source of bacteria in stormwater runoff includes livestock operations, failing septic systems, unusually high concentrations of pet and wildlife droppings, leaking sewer lines, illicit connections between storm and sanitary lines, combined sewer overflows, etc. High concentrations of bacteria often result in the closure of public recreational uses of water resources, and may increase the cost of treatment for domestic water use.

*Hydrocarbons*. Hydrocarbon loading in urban runoff is often associated with automobile engine oil, lubricants, and other compounds. Hydrocarbon levels have been found to be highest in the runoff from parking lots, roads, and service stations.

*Trace metals.* Trace metals found in urban runoff, such as cadmium, copper, lead, and zinc, originate from a wide variety of sources such as roofing materials, down spouts, galvanized pipes, catalytic converters, brake linings, etc. Over time these surfaces wear down, enabling the metals to wash away in urban runoff.

*Biological Oxygen Demand (BOD)*. Decomposition of organic matter in slow moving receiving water bodies such as lakes and estuaries increases the biological oxygen demand. High BOD depletes the available dissolved oxygen (DO) necessary to sustain aquatic life.

*Thermal Impacts*. Runoff from urban impervious surfaces can significantly increase ambient temperatures in receiving streams. Paved surfaces transfer significant amounts of thermal energy to runoff passing over it. When this warmed runoff reaches the receiving stream, a rise in temperature of just a few degrees can have a adverse impact on aquatic life.

### 2-1.2 Stream Channel Erosion

The impact of increased stormwater runoff can be easily observed in an urbanized stream system. Most of the drainage network is developed or improved to convey increased volumes and rates of runoff to the receiving stream channel. The stream channel then responds to the increase in flow by eroding to form a larger cross sectional flow area which, theoretically, should result in reduced flow velocities. An eroded channel, however, is quite often a very efficient conveyance system and promotes an even faster velocity of flow, which in turn, accelerates the channel erosion process. Once this process has begun, it is very difficult to stop because typical stream channel soils are highly erodible once the protective lining of cobble or vegetation is eroded away.

### 2-1.3 Flooding

When the rate of stormwater runoff exceeds the capacity of the various manmade or natural conveyance systems, the result is localized flooding. The conveyance system gradually catches up and drains the flood waters as the rainfall subsides. In some cases debris or other materials dislodged by the rising flood waters will clog the drainage system and cause longer periods of flooding. In either case, pockets of standing water which do not drain will remain for periods of time and eventually percolate into the ground or evaporate.

In the pre-developed condition, most stream channels have an adequate floodplain or flood fringe to convey and store the out of bank flows with minimal damage. With urbanization, however, these floodplain areas are often eliminated or developed with improvements. The periodic ponding of water in developed areas often results in damage. Pavement will fail or be undermined, structures will be water damaged, landscaping and other improvements not used to inundation will be damaged.

### 2-1.4 Regional (watershed-wide) Stormwater Plans

The cumulative effect of sedimentation, scouring, increased flooding, lower summer flows, higher water temperature, and pollution contribute to the overall degradation of the stream ecosystem. Many studies have documented the decline of fish diversity in urbanized watersheds. The aquatic insects which are a major food resource for fish are impacted by the increased sediment load, trace metals, nutrients, and flow velocities. Less noticeable impacts to the stream systems are changes in water temperature, oxygen levels, and substrate composition.

A regional or watershed-wide stormwater plan provides the framework needed to evaluate the impacts of changes to the land on water resources. A comprehensive watershed management plan considers all of the impacts of increased stormwater runoff: water quality, channel erosion, and flooding. The plan is the result of studying the environmental features of the watershed to identify those areas that should be protected and preserved. The plan identifies and strategically locates stormwater management measures and design criteria to be utilized to protect the watershed. The plan also aims to utilize and protect ecological processes to lessen the need for structural control methods that require capital costs and maintenance.

## 2-2 BMP SIZING CRITERIA

Stormwater management policies have been developed over the years in an attempt to mitigate the impact of land development on aquatic systems as discussed previously. Increased flash flooding and the associated flood damage in urbanizing areas gave rise to stormwater management policies based on controlling peak discharge. In addition to the structural damage, significant erosion of the channel bed and banks was considered to be a detriment to the value of property. Detention basins sized to reduce the post-development peak discharge to the pre-developed rates became an acceptable and commonly used method of mitigating these impacts of urbanization. As channels eroded, more and more localities developed peak rate control policies aimed at controlling channel erosion and localized flooding. These policies, however, were still based on a peak rate of discharge and did not address the increased *volume* and *frequency* of the peak discharge.

Both theory and experience indicates that, while detention basins designed to control peak discharge are effective in controlling peak rates, the basins are ineffective in controlling the degradation of erodible channels downstream of the basin. (McCuen, Moglen, 1988). Similarly, detention basin design must incorporate methods for improving water quality. The following discussion provides a discussion of various sizing criterion for stormwater quality, stream channel erosion, and flood control BMPs.

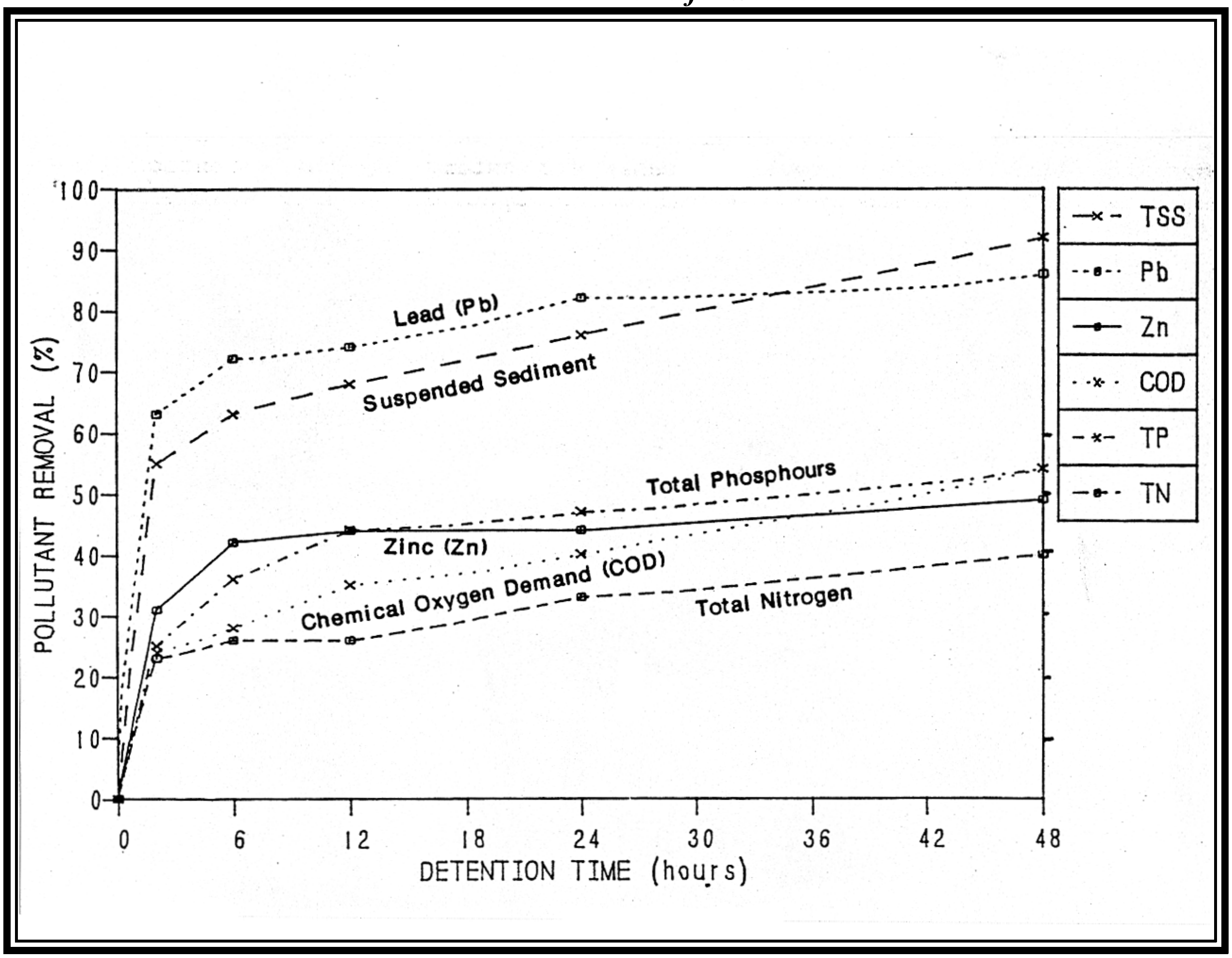
### 2-2.1 Water Quality

<u>Pollutant Removal Mechanisms</u>

Pollutant removal mechanisms employed by urban BMPs include *settling*, *filtering*, and *biological processes*.

*Settling* or *sedimentation* is limited to particulate pollutants which drop out of the water column by way of gravitational settling. In some cases, pollutants will attach themselves to heavier sediment particles or suspended solids and drop out of the water column. Laboratory and field studies indicated that significant settling of urban pollutants occurs in the first 6 to 12 hours of detention. **Figure 2-1** provides removal rate vs detention time for selected pollutants. The brim draw down requirement for water quality extended detention design is 30 hours, rather than the minimum of 6 to 12 hours. The additional time is required to allow for ideal settling conditions to develop within the stormwater facility. In addition, the added time will allow for settling of smaller particle sizes and nutrients, as well as increasing the opportunity for biological processes. Stormwater BMPs which utilize settling are usually suited for dual purposes, that is they can also provide storage volume for peak rate control, channel erosion, and/or flood control. These impoundment water quality BMPs are generally sized based on a volume of runoff, commonly referred to as the *water quality volume* (WQV), or "first flush" of runoff. The water quality volume is discussed in detail later in this section.

**FIGURE 2-1**
*Removal Rate vs. Detention Time for Selected Pollutants*




Source: Schueler, Controlling Urban Runoff, 1987

*Stormwater filtering* or *filtration* is typically limited to BMPs which address water quality. These facilities utilize a filter media, such as sand, peat, grass, compost, or various types of fabrics or other material to strain pollutants out of the stormwater. Since the stormwater must pass through the filter media in order to be treated, these structures are limited to small drainage areas (less than 5 acres) and low flow rates. A drawback to these structures is the overflow or bypass of large flows from high intensity storms. The current sizing criteria for these BMPs is the water quality volume. The Department is currently evaluating the option of designating a flow rate or return frequency intensity for design purposes. In most cases a bypass or diversion structure is needed to allow large flows to bypass the BMP without flushing previously deposited pollutants out of the BMP. Guidance on this issue will be provided in the future.

*Biological processes* are the most effective removal mechanisms for soluble pollutants, such as nutrients. A combination of shallow permanent pool depths and abundant vegetation help to create conditions which allow a natural food chain to develop. Marsh plants, algae and bacteria that grow on the shallow organic rich sediments can take up soluble forms of nutrients needed for their growth. BMPs suited for this pollutant removal mechanism include enhanced extended detention, retention, constructed stormwater wetlands, and in some cases bioretention. The sizing criteria for these BMPs is generally based on permanent pool volume defined as a multiple of the water quality volume, IE: 2.0 or 3.0 times the WQV. (Bioretention utilizes filtering as the primary pollutant removal mechanism.)

**Table 2-1** identifies the pollutant removal mechanism utilized by each of the BMPs listed in Table 1 of the Virginia SWM Regulations. It should be noted that the Manufactured BMP Systems are not itemized in **Table 2-1**. For further discussion of Manufactured BMP Systems, refer to **Minimum Standard 3.15**.

**TABLE 2-1**
***Pollutant Removal Mechanisms***

| Water Quality BMP | Settling | Filtering | Biological |
|---|---|---|---|
| Vegetated filter strip | | U | |
| Grassed swale (w/ check dams) | U | U | |
| Constructed wetlands | U | U | U |
| Extended detention | U | | |
| Extended detention enhanced | U | U | U |
| Bioretention | | U | U |
| Retention basin I, II | U | | U |
| Retention III | U | | U |
| Sand filter | | U | |
| Infiltration | | U | |

Many stormwater BMPs will utilize a combination of these pollutant removal mechanisms. In some cases, after a BMP has been in operation for a period of time, a layer of organic matter will develop within the BMP, thereby increasing the adsorption potential of the BMP. *Adsorption* is the chemical or molecular attraction which enhances the removal of soluble pollutants. BMPs which include plants and grasses also display increased pollutant removal efficiency over time as the biomass increases. As the vegetation thickens, it serves to slow the velocity of the runoff through the BMP. This allows for increased gravitational settling and filtering of pollutants, as well as decreased export of sediment and attached pollutants via erosion.

Water Quality Volume (WQV)

Ideally, the pollutant removal mechanism should dictate the treatment volume or frequency storm for water quality BMPs. The sizing of BMPs which utilize gravitational settling of pollutants as the removal mechanism can be based on a volume of runoff, while BMPs which utilize filtering should probably be based on a flow rate or frequency. Design criteria provided in **Chapter 3: BMP Minimum Standards**, specifies maximum flow velocities for grass swales and filter strips, as well as the need for a flow splitter or bypass structure for sand filters and other flow through structures.

The Virginia Stormwater Management Regulations require that the *first flush* of runoff be captured and "treated" to remove pollutants. The first flush, or water quality volume (WQV) is generally defined as the first ½" to 1" of runoff from impervious surfaces. Other methods of defining this first flush have been developed. One method in particular, developed by The Center for Watershed Protection, utilizes the Runoff Frequency Spectrum (RFS) for the Washington D.C. area and surrounding Chesapeake Bay watershed. The RFS is based on the fact that 90% of the annual runoff is generated by storms of 1" of rainfall or less. Therefore, the goal of treating at least 90% of the annual runoff results in a treatment volume based on a 1" rainfall. The volume of runoff is determined by multiplying a volumetric runoff coefficient ($R_v$), based on site imperviousness, by the 1" of rainfall. This method generates a water quality volume of close to 1" for highly impervious sites and gradually decreasing volumes for gradually decreasing levels of imperviousness.

***As noted in the Virginia Stormwater Management Regulations, water quality BMPs which are dependent on volume, such as extended detention, constructed stormwater wetlands, and in some cases infiltration, have a required treatment volume of 2.0 x WQV (or 2.0 x 0.5" = 1.0" per impervious acre). This will result in a very similar volume as that based on the RFS method described above. As these methods are studied and BMPs are monitored, the design criteria for determining the WQV may be refined to achieve a greater overall level of treatment.***

While the first flush from a storm event is considered to contain the highest concentration of pollutants, there is considerable debate over the intensity of rain needed to wash the pollutants from the urban landscape. Studies have shown that intensity is the critical wash off factor for most storm events, and many people can intuitively comprehend that higher intensity rains leave impervious surfaces cleaner than lower intensity rains. (Adams, 1997). The typical SCS rainfall hyetograph starts with a low rainfall intensity which gradually rises to a peak and then declines. This may indicate that in some cases the designated water quality volume provided in a stormwater basin may fill up with the relatively clean water at the onset of a rain event, consequently allowing the larger flows associated with the high intensity rain and pollutant wash off to pass through the facility.

A similar discussion on the design criteria for water quality structures focuses on the "volume" of runoff verses the "rate", or even the return frequency, of runoff. The water quality volume or first flush is detained in a basin or impoundment structure to allow the pollutants to settle out. Whether that specific volume of runoff enters the basin gradually, or as the result of a sudden high intensity rain, it is still detained for a period of time. Filtering structures, on the other hand, can handle only a certain design flow rate. Sudden high intensity rain will typically generate too much runoff too fast and therefore bypass the treatment facility.

A new category of water quality BMPs: Manufactured BMP Systems (**Minimum Standard 3.15**), utilizes combinations of settling, swirl concentration, and filtering to separate pollutants from the runoff. These structures vary in how they respond to high flows. Some will bypass large flows with little or no treatment, while others will continue to separate and treat the runoff at a reduced efficiency. Further study of these manufactured systems and the appropriate design criteria for flow through or hydro-dynamic structures is warranted and will be provided at a future time.

### 2-2.2 Stream Channel Erosion

Stream channel erosion results primarily from high scour velocities over extended durations of time. Studies show that natural channels are shaped by the 1½- to 2-year frequency storm event. (Leopold et al., 1964; Anderson, 1970). This frequency allows the channel to maintain a state of equilibrium with regard to the natural sediment load transport and natural vegetation which helps to stabilize channel banks. Therefore, local ordinances have traditionally regulated the 2-year storm, specifying that the post-developed peak rate of runoff may not exceed the pre-developed rate. Note, however, that this requirement does not address the increase in the *frequency* of that peak runoff rate. Urbanization usually increases the amount of impervious cover, resulting in less infiltration, less initial abstraction and less depression storage. Consequently, it takes less rainfall to produce the same *volume* of runoff. Therefore, the *peak rate of runoff* that normally occurs on a 2-year frequency before development, may occur several times a year following development.

To compound the problem, a detention basin stores the increased *volume* of runoff from a developed area and releases it at the pre-developed rate. The *duration* of this discharge is much longer than the pre-developed condition. The peak rate and velocity may be at pre-developed levels, but by receiving the pre-developed rate for a longer *duration*, coupled with the increase in *frequency*, a stable earth-lined channel can quickly degrade.

The increased frequency of a specific discharge can be illustrated by considering an undeveloped watershed which, during a 2-year frequency storm (3.2 inches of rain), generates a theoretical peak rate of runoff of 15 cfs, and a corresponding volume of runoff of 0.52 watershed inches. We will assume that this 2-year frequency flow represents the channel forming, bankfull discharge. After the watershed has experienced development (32% imperviousness) along with the associated improved drainage conveyance systems, the same watershed requires only 1.6 inches of rainfall to generate that same theoretical bankfull discharge of 15 cfs. This means that the channel will now experience bankfull flows at an approximate increased *frequency* of every three to six months rather than two years. In addition, for the 2-year storm, the *volume* of runoff has increased to 1.15 watershed inches, more than double the pre-developed volume, which means a significant increase in the *duration* of the peak flow can be expected. Under this scenario, the receiving stream will experience a significant increase in erosive flows.

The solution to designing for stream channel erosion is evolving into a study of stream channel geomorphology. Several studies have indicated that the level of erosion (or bed-material load) is a function of the difference between the flow velocity and the *critical* velocity.(McCuen, 1987). The critical velocity is a function of the type of soil of which the channel bed is composed. The studies indicate that the amount of bed sediment moved is a function of the time duration over which the velocity is greater than the critical velocity. According to McCuen, this explains from a conceptual standpoint why the duration of flow is just as important as the rate of flow. Further, it may explain why detention basins may actually increase the erosion compared to providing no control of the post-developed flows. When no control is provided, the flow tends to exceed the channel capacity and extend out into the floodplain; thus the velocity within the channel banks may not increase significantly even though the peak flow rate does increase significantly.

This should not be interpreted as justification for no control of stormwater runoff. Rather, it highlights the need for a design criteria that replicates the pre-development sediment load transport characteristics of the channel. Several methodologies have been recommended, some of which are very subjective as they are based upon the ability of the designer to analyze and interpret the stream sediment characteristics. This could easily become an expensive and cumbersome methodology, especially in localities that do not experience significant development pressure. The review and approval process could become bogged down in the analysis of field data and trying to verify the channel characteristics, especially when the requirements of the field work may be different for every project.

The Virginia Stormwater Management Regulations address stream channel erosion by requiring compliance with Minimum Standard 19 of the Virginia Erosion and Sediment Control Regulations (4VAC50-30-40.19). This standard requires that **properties downstream from development sites be protected from sediment deposition, erosion, damage due to increases in volume, velocity, and peak flow rate of stormwater runoff**. The specific design criteria specifies that downstream *natural channels* by analyzed for adequacy to convey the developed condition 2-year peak discharge within the channel banks and at a non-erosive velocity. In addition, *man made channels* are analyzed for adequacy to convey the 10-year peak discharge within the channel banks and the 2-year peak discharge at a non-erosive velocity.

When a channel is determined to be not adequate, the use of a stormwater detention BMP sized to discharge the 2-year and 10-year frequency developed-condition peak discharge at the respective pre-developed rates is one of the available options. (Refer to **Chapter 1** for the complete language of Minimum Standard 19.) As we discussed above, this criteria may not be adequate for natural channels due to the increase in the frequency, duration, and volume of the “pre-developed” discharge.

An alternative is to identify a design frequency storm and control the discharge such that it does not exceed that of the critical velocity for the channel. Recent studies have shown a significant reduction in stream channel erosion below facilities designed to provide 24-hour extended-detention of the runoff from the 1-year frequency storm. (Galli MWCOG, 1992). This criteria results in significantly lowered discharge rates and velocities considered to be non-erosive, despite the longer impact time and increased frequency. The Virginia SWM Regulations allow this criteria as an alternative to the 2-year peak discharge control requirement in cases where natural channels are experiencing erosion resulting from existing conditions, or where channels are considered to be sensitive to any increase in flow rate or duration.

***Further guidance on the analysis of the adequacy of natural channels, consistent with the Erosion and Sediment Control Regulations will be provided by the DCR in the near future.***

### 2-2.3 Flooding

Control of the 10-year frequency design storm to the pre-developed rate is considered to provide control over a wide range of storms for control of localized or out of bank flooding. This should not be confused with out of bank flooding as it pertains to the 100-year floodplain which is mapped by the Federal Emergency Management Agency (FEMA), and based on the 100-year frequency design storm. The mapped 100-year floodplain is important because it is used to designate and implement the National Flood Insurance Program. Most localities in Virginia have a Floodplain Management Ordinance which controls development within the 100-year floodplain.

### 2-2.4 More Stringent Criteria

Local programs are authorized under the Virginia Stormwater Management Act to require more stringent technical criteria than the state minimum criteria found in the regulations (4VAC3-20). The more stringent criteria must be based on a watershed plan or study which justifies the criteria, and must be passed into local ordinance through the local ordinance adoption process. The scope of an acceptable watershed plan or study is somewhat subjective and, at a minimum, must stand up to the scrutiny of the local adoption process. Some basic watershed plan concepts are provided in **Section 2-4**.

## 2-3 BMP SELECTION CRITERIA

The following discussion provides a general outline for choosing the appropriate BMPS for a development site. The order of presentation **does not** imply a decision making process that will systematically progress towards an acceptable BMP. On the contrary, any one of the criteria can render a preferred BMP unacceptable. **In some cases**, the designer may be able to accommodate certain limiting feasibility factors by providing an innovative design which addresses or remedies the constraint. **In all cases**, once a BMP is selected, we strongly recommend that the selection, along with the supporting criteria and any compromises or design features, be presented to the various review or permitting agencies to ensure proper evaluation and review. This will help avoid extensive changes to the stormwater management strategy during the review process.

One of the first considerations in selecting a stormwater BMP is the functional goal of the BMP. Previously, we discussed the components of SWM: *stormwater quality*, *stream channel erosion*, and *flooding*. Any one or combination of these components may be addressed by the local ordinance and will dictate the functional goal of the BMPs. (State agency projects, are required to comply with all three of these regulatory components). In general, stormwater BMPs can be categorized into water *quality* BMPs and water *quantity* (stream channel erosion and flooding) BMPs. **Table 2-2** provides a general categorization of BMPs by functional goal. Note, that some BMPS can be designed to satisfy both quality and quantity goals while others are specifically suited for only one.

The use of some BMPS are limited by site or watershed feasibility factors such as environmental impacts, drainage area or watershed size, and topographic constraints.

Finally, the BMPS designed for water quality control provide varying levels of pollutant removal and are suited for specific development densities. **Table 2-3** presents a generic list of water quality BMPS, their target phosphorus removal efficiency, and appropriate percent impervious cover.

The decision making process of choosing a stormwater BMP must weigh the goals of the proposed facility against the limiting site feasibility factors of the proposed site or BMP location. The limiting *site feasibility* factors include:

1. Topographic and geologic constraints,
2. Contributing drainage area size, and
3. Environmental impacts.
4. Access for maintenance

The possible stormwater management requirements or goals which influence BMP selection include:

1. Multiple Criterion: Stormwater quality, stream channel erosion, flooding, and environmental mitigation,
2. Multiple discharge points,

3. Pollutant removal capability, and
4. Performance-based vs technology-based water quality criteria.

### 2-3.1 Site Feasibility

### 1. Topographic and Geologic Constraints

The physical characteristics of the site must be compatible with the performance of the BMP. Reviewing the **Minimum Standards** found in **Chapter 3**, you will note that BMPs are restricted in certain areas based on the geologic or underlying conditions. This can be as simple as determining if the hydrologic soil group is appropriate for the BMP (such as infiltration in permeable soils) or may require a vigorous geotechnical investigation.

a. *Karst topography:* Karst topography consists of geologic formation underlain by carbonate rock and typified by the presence of limestone caverns and sink holes. These areas present very difficult challenges since any BMP which impounds water may cause underlying caverns or sink holes to expand and open at the surface. The use of liners may help the BMP hold the runoff as intended, however, the conveyance to the BMP, as well as the conveyance from the BMP to the receiving channel must also be considered since the overall volume of runoff is increasing and possibly being directed to areas previously not impacted by runoff.

   In addition, the presence of karst may allow a direct path for the stormwater runoff to enter the water table with little or no filtering of pollutants. Any design in regions suspected to include karst topography should be supported by a thorough subsurface geotechnical or geological investigation. Further guidance on geotechnical methods for karst topography will be provided by the Department in the near future.

b. *High water table*: A high water table can impact the proper functioning of a BMP. Infiltration BMPs are restricted since a high water table will prevent the percolation of the stormwater into the sub soils. A high water table may cause dry detention BMPs to evolve into wet facilities. While this may enhance pollutant removal by encouraging a marsh environment, it may not be the choice of design based on maintenance, aesthetics, etc. A high water table may also impact the construction of the embankment or impoundment facilities by making it difficult to achieve the proper compaction of the underlying foundation. Special geotechnical recommendations may be necessary to address impacts associated with a high water table.

c. *Bedrock:* The presence of bedrock close to the surface can have a significant impact on a development project. The cost of excavation increases considerably, especially if blasting is required. Blasting rock in the area of a proposed embankment is not acceptable unless a liner system is proposed for the basin. Blasting can open seams in the bedrock which may allow stormwater to drain out of (or under) the proposed facility.

A thorough geotechnical investigation and report should verify the subsurface conditions for the presence of any of the above features. The scope and requirements of a geotechnical investigation may vary from site to site. Refer to **Minimum Standard 3.10: General Infiltration Practices** for additional information on geotechnical investigations.

d. *Proximity to structures, steep slopes, and water supply wells.* One of the goals of stormwater facilities is to provide recharge of the groundwater. This tends to saturate the adjacent ground during, and for a period of time, after, a storm event. Building foundations, basements, and other structures may be impacted by the wet/dry cycle of the surrounding soils.

   Saturating the soils on or adjacent to steep slopes (6 to 10 percent or greater) can cause a failure of the slope and adjacent structures.

   The proximity to water supply wells raises concern over the introduction of pollutants into the water supply aquifer. Minimum distances from these features are presented in **Chapter 3: Minimum Standards**.

### 2. Contributing Drainage Area Size

Some BMPs are restricted based upon the size of the contributing drainage area. The recommended maximum and minimum sizes are considered guidelines and some flexibility should be allowed. The exceptions, however, are the Manufactured BMP Systems (**Minimum Standard 3.15**) The manufacturers design criteria should be adjusted or modified **by the manufacturer only**. The proper operation of these BMPs is dependent on the proper sizing of the structure.

### 3. Environmental Impacts

It is extremely important for the designer to asses the environmental impacts associated with the site development and the placement of the stormwater BMP. Local, State, and Federal regulations may restrict the disturbance, or encroachment upon any of the following: wetlands, Waters of the United States, stream or wetland buffers, floodplains, conservation easements, and other sensitive resources.

*Virginia Water Protection Permit Program*: The Virginia Department of Environmental Quality implements the Virginia Water Protection Permit (VWPP) Program. This program regulates all activities in Virginia which result in discharge or dredge or fill material into state waters. This can include wetlands, perennial streams, and other aquatic resources. The VWPP program is in conjunction with the U.S. Corps. of Engineers Federal Permit authorized by the Clear Water Act. Some projects may require one or both permits. The permit typically requires that the developer investigate alternatives to the proposed impacts. If no alternatives are viable, then possible design modifications may be needed, such as pre-treatment of stormwater prior to discharging into wetlands, thermal and dissolved oxygen impacts to the receiving stream be addressed, etc. The designer should contact the appropriate state or federal agencies prior to the design to identify such permit requirements.

*Chesapeake Bay Preservation Act*: The Chesapeake Bay Preservation Act (CBPA) and regulations, implemented by local governments, contain restrictions on development within certain buffer areas of wetlands, streams and other sensitive water resources. The designer should contact the Chesapeake Bay Local Assistance Department or the local government prior to the design to identify the restricted buffer areas and other requirements of the CBPA and regulations.

*National Flood Insurance Program*: The Department of Conservation and Recreation (DCR) coordinates the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) in Virginia. Local governments implement local floodplain management ordinances consistent with the state and federal statutes. The designer should contact DCR or the local government prior to design in order to identify any mapped 100-year foodplain located on the project.

### 2-3.2 Site or Watershed Stormwater Management Requirements

#### 1. Multiple Criterion: Quality, Stream Channel Erosion, and Flooding

The functional goal of the stormwater BMP will be determined by the regulatory requirements imposed on the site. In some cases the downstream receiving waters will influence the regulatory requirements. Where multiple controls are required (quality and quantity), ideally these controls can be satisfied in one BMP strategically located on the site. This is usually accomplished with an impoundment BMP such as *extended detention* or *retention*.

On small sites, however, the use of impoundment facilities is limited by the available space, and their inability to adequately serve small areas for water quality. (The small orifice diameter required for adequate extended detention time can easily become a maintenance burden for a small site, and the contributing drainage area size should be at least 25 acres or contain a base flow when considering a retention basin.) Therefore, it may become necessary to utilize more than one BMP: one which addresses quantity and another which addresses quality. Reducing the stormwater quantity requirements through non-structural BMPs or innovating site design techniques will help to reduce the need for structural quantity control BMPs which typically are land intensive.

## 2. Multiple Discharge Points

The simplest site design includes a stormwater management strategy that consists of one discharge point from the site. Large developments, however, often contain multiple discharge locations as dictated by the topography. Traditionally, this situation has been addressed one of two ways: 1) Provide a Stormwater BMP at each location as required by the size of the contributing drainage area and associated increase in peak discharge, percent imperviousness, etc; or 2) overcompensate at one discharge point in order to allow the other discharge point(s) to go uncontrolled.

*Overcompensation of Peak Discharge* should be subject to the following conditions:

1. The drainage channels which leave the site must be part of the same stream or tributary network and the confluence should occur at some reasonable distance from the site.

2. The uncontrolled discharge is still subject to the requirements of MS-19, that is the receiving channel is adequate to convey the increased flow.

3. The overall peak rate of discharge leaving the site must not exceed that of the pre-developed condition.

*Overcompensation of Water Quality* is covered in more detail in the next section which discusses the use of the Performance-based Water Quality Criteria. However, as it applies to multiple discharge points, the following conditions should apply:

1. The drainage channels which leave the site must be part of the same stream or tributary network and the confluence should occur at some reasonable distance from the site.

2. Every effort should be made to provide water quality enhancement through the use of vegetated buffers, open grass/vegetated swales, bioretention, or other low maintenance water quality BMPs.

3. Every effort should be made to minimize the impacts in the uncontrolled drainage area through non-structural means as discussed previously.

4. The overall site water quality compliance must be determined using the performance-based water quality criteria.

Another alternative which may be considered is the control of existing development in lieu of the proposed development. This trade off should be considered only if specific site, watershed, or environmental considerations hinder the successful incorporation of on-site BMPs.

## 3. Pollutant Removal Efficiency

Years of pollutant removal monitoring of stormwater BMPs has provided us with a basic understanding of how efficient various BMPs are at removing urban pollutants. Most of this knowledge is limited to the older and more traditional impoundment BMP structures such as *retention* and *extended detention*. Recent regulatory requirements focused on reducing the export of nonpoint source pollution have given rise to new BMPs, some of which have had very limited monitoring with which to verify removal efficiencies. The pollutant removal efficiencies provided in the stormwater regulations and this handbook are derived from the best available information. We recognize that these values are subject to change as we learn more about the practical application and maintenance of these new BMPs.

Keystone Pollutant

The pollutant removal efficiencies presented in **Table 2-4** are removal efficiencies for phosphorus. This target or keystone pollutant was selected by the Chesapeake Bay Local Assistance Department in order to evaluate the performance of site design and BMPs at reducing pollutant export from a development site. The selection of one pollutant allows a consistent application of a performance based water quality criteria. Phosphorous was selected because it exhibits some of the characteristics of particulate pollutants, as well as those of soluble pollutants, making it a good indicator of urban pollutants in general. This is not meant to exclude other pollutants from being targeted. The performance-based water quality calculation procedure was originally adopted as guidance in the Chesapeake Bay Local Assistance Department's *Local Assistance Manual* for localities implementing Chesapeake Bay Preservation Act (CBPA) programs. In situations where other pollutants are identified as a problem, such as from "stormwater hotspots", those other pollutants should be addressed.

Stormwater Hotspots

*Stormwater hotspots* are defined as a land use or activity that generates higher concentrations of a particular pollutant or pollutants, such as sediment, hydro-carbons, trace metals, or toxicants, than are found in typical stormwater runoff, based on monitoring studies. (Center for Watershed Protection, 1997). The use of some BMPs are limited on sites considered to be stormwater hotspots. This is due to the potential for the contamination of groundwater. *Infiltration facilities* are not recomended for hotspots for this reason. Further, the use of impoundment type structures for hotspots should be qualified by an adequate separation from the seasonal groundwater table (four foot separation is desirable, and a two foot separation minimum), or an impermeable liner used to prevent leachate infiltration

**TABLE 2-2**
***Functional Goal of Stormwater BMPs***

| Stormwater BMP | Quality | Stream Channel Erosion | Flooding |
|---|---|---|---|
| Vegetated filter strip | U++ | | |
| Grassed Swale (w/ check dams) | U++ | U | |
| Constructed wetlands | U++ | U | |
| Extended detention | U+ | U++ | U |
| Extended detention enhanced | U++ | U+ | U |
| Bioretention | U++ | | |
| Retention basin | U++ | U+ | U |
| Sand filter | U++ | | |
| Infiltration | U++ | | |
| Infiltration Basin | U+ | U | U |
| Detention | | U+ | U++ |
| Manufactured BMPs | U++ | | |

Legend: U++ = Primary functional goal

U+ = Potential secondary functional goal

U = Potential secondary functional goal with design modifications or additional storage

**NOTE:** *Some BMPs, when properly designed, can provide secondary goals. Table 2-2 indicates several water quality BMPs with potential secondary goals. This is not meant to restrict the designer from incorporating design modifications or additional storage as appropriate for the particular site. Care must be taken to ensure that the the design modifications do not diminish the primary goal capabilities of the BMP.*

**TABLE 2-3**
***Target Phosphorus Removal Efficiency****

| Water Quality BMP | Target Phosphorus Removal Efficiency | Percent Impervious Cover |
|---|---|---|
| Vegetated filter strip<br>Grassed swale | 10%<br>15% | 16-21% |
| Constructed wetlands<br>Extended detention (2 x WQ Vol)<br>Retention basin I (3 x WQ Vol) | 30%<br>35%<br>40% | 22 -37% |
| Bioretention basin<br>Bioretention filter<br>Extended detention-enhanced<br>Retention basin II (4 x WQ Vol)<br>Infiltration (1 x WQ Vol) | 50%<br>50%<br>50%<br>50%<br>50% | 38 -66% |
| Sand filter<br>Infiltration (2 x WQ Vol)<br>Retention basin III (4 x WQ Vol with aquatic bench) | 65%<br>65%<br>65% | 67 -100% |

** Innovative or alternate BMPs not included in this table may be allowed at the discretion of the local program administrator or the Department. Innovative or alternate BMPs not included in this table which target appropriate nonpoint source pollution other than phosphorous may be allowed at the discretion of the local program administrator or the Department.*

**TABLE 2-4**
***Classification of Stormwater Hotspots***

| |
|---|
| The following land uses and activities are deemed *stormwater hotspots*<br>< vehicle salvage yards and recycling facilities #<br>< vehicle fueling stations<br>< vehicle service and maintenance facilities<br>< vehicle and equipment cleaning facilities #<br>< fleet storage areas (bus, truck, etc.) #<br>< industrial sites (for SIC codes contact Virginia Dept. Of Environmental Quality)<br>< marinas (service and maintenance) #<br>< outdoor liquid container storage<br>< outdoor loading/unloading facilities<br>< public works storage areas<br>< facilities that generate or store hazardous materials #<br>< commercial container nursery |
| # indicates that the land use or activity is required to prepare a stormwater pollution prevention plan in accordance with the Virginia Pollution Discharge Elimination System program permit as required by the Virginia Department of Environmental Quality. |

Source: Center for Watershed Protection, 1997

### 2-3.3 *Technology-Based* and *Performance-Based* Water Quality Criteria

The *Technology-based* and *Performance-based* water quality criterion represent a consolidation of the water quality technical criteria of three state agencies charged with the responsibility of monitoring and improving the water resources of the Commonwealth: The Department of Conservation and Recreation (DCR), the Department of Environmental Quality (DEQ), and the Chesapeake Bay Local Assistance Department (CBLAD). The specific responsibilities of these agencies are presented in **Chapter 1**. The stormwater management water quality regulations require compliance by **either** a *performance-based water quality criteria* **or** a *technology-based water quality criteria*.

The *performance-based* water quality criteria states that for land development, the calculated post-development nonpoint source pollutant runoff load shall be compared to the calculated pre-development load based upon the average land cover condition or the existing site condition. This approach requires the designer to calculate the pollutant load to be removed, implement a BMP strategy, and then calculate the performance of that strategy, based on the effectiveness or pollutant removal efficiency of the selected BMP(s), (**Table 2-3**) .

The calculation procedure for verifying compliance with the performance-based water quality criteria is based on the Simple Method. The *Simple Method* is empirical in nature and utilizes the extensive data base obtained in the Washington D. C. National Urban Runoff Pollution (N.U.R.P.) study, as well as the national N.U.R.P. data analysis (MWCOG, 1983) to establish pollutant loading values for various land uses. The derivation of the Simple Method can be found in Appendix A of Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, published by The Metropolitan Washington Council of Governments.

The *technology-based* water quality criteria states that for land development, the post-developed stormwater runoff from the impervious cover shall be treated by an appropriate BMP as required by the post-developed condition percent impervious cover as specified in **Table 2-3**. The selected BMP shall be located, designed, and maintained to perform at the target pollutant removal efficiency specified in **Table 2-3**.

These two criterion are considered to be equivalent when implemented as described in this handbook. The design criteria found in **Chapter 3** establishes the minimum design elements which should result in the expected pollutant removal performance of the BMP.

### 1. Performance-Based Water Quality Criteria

The *performance-based water quality criteria* states that for land development, the calculated post-development nonpoint source pollutant runoff load shall be compared to the calculated pre-development load based upon the average land cover condition or the existing site condition. A BMP shall be located, designed, and maintained to achieve the target pollutant removal efficiencies specified in **Table 2-3** to effectively reduce the pollutant load to the required level based upon the following four applicable land development situations for which the performance criteria apply:

1. *Situation 1* consists of land development where the existing percent impervious cover is less than or equal to the average land cover condition and the proposed improvements will create a total percent impervious cover which is less than the average land cover condition.

   Requirement: No reduction in the after development pollutant discharge is required.

2. *Situation 2* consists of land development where the existing percent impervious cover is less than or equal to the average land cover condition and the proposed improvements will create a total percent impervious cover which is greater than the average land cover condition.

   Requirement: The pollutant discharge after development shall not exceed the existing pollutant discharge based on the average land cover condition.

3. *Situation 3* consists of land development where the existing percent impervious cover is greater than the average land cover condition.

> Requirement: The pollutant discharge after development shall not exceed (i) the pollutant discharge based on existing conditions less 10% or (ii) the pollutant discharge based on the average land cover condition, whichever is greater.

("...which ever is greater" refers to the calculated pollutant discharge to which the after development pollutant discharge is compared. Additional explanation is provided in the discussion following this section.)

4. *Situation 4* consists of land development where the existing percent impervious cover is served by an existing stormwater management BMP that addresses water quality.

> Requirement: The pollutant discharge after development shall not exceed the existing pollutant discharge based on the existing percent impervious cover while served by the existing BMP. The existing BMP shall be shown to have been designed and constructed in accordance with proper design standards and specifications, and to be in proper functioning condition.

The definition of the average land cover condition is important to the successful implementation of the performance-based water quality criteria. An analysis of the Chesapeake Bay watershed identified the average land cover condition using the following categories: urban land use, forest cover, pasture land, conservation till acreage, and conventional till acreage. Using the pollutant load values from the N.U.R.P. studies, the average land cover condition was then used to establish a baseline existing land use condition pollutant load value of 0.45 lb/ac/yr of phosphorous. Since the Simple Method is based on impervious cover, an equivalent percent impervious cover is needed. 16% impervious cover has been determined to be an equivalent pollutant load source for all of the urban and non-urban land uses which contribute nonpoint source pollution. These values (16% impervious cover and 0.45 lb/ac/yr of phosphorous) represent the average land cover conditions for the Chesapeake Bay watershed. (Keep in mind that these values may be adjusted based on actual land use conditions within the locality or individual watersheds within the locality at the time of DCR or CBLAD program adoption, whichever occurred first.) This allows the designer to calculate, using the Simple Method, the pre-developed pollutant load using average land cover conditions, and the post-developed pollutant load using the project post-developed impervious cover. The difference between the pre- and post-developed pollutant load represents the increase in pollutant load which must then be controlled by an appropriate BMP.

***Since this methodology is based on impervious cover, there may be some developments such as golf courses, cemetaries, etc. which would be calculated as having no increase in pollutant load. Depending on the pre-developed land cover, this may or may not be the case. Unmanaged meadow which is graded into a golf course fairway will probably experience an increase in pollutant discharge. Since this is not accounted for in the calculation procedure, the designer and reviewer are encouraged to use sound engineering judgement in applying the water quality criteria. Site feasibility factors should be evaluated and an appropriate BMP selected in situations where the calculation procedures do not accurately reflect the post developed condition impact on water quality.***

The designation of an average land cover condition helps to prevent extreme compliance situations. Without such a provision, a site in its natural state with very little runoff and NPS pollution, e.g. a forested site, might become impossible to develop simply because currently available BMPs may not be able to satisfy the pollutant removal requirement of *post* back to *pre*. Conversely, a development of open land with sparse vegetation may generate a significant pre-development load such that careful development of the site, without the use of BMPs, may satisfy the rpollutant removal standard. The concept of average land cover condition attempts to provide a balance in implementing the performance-based and technology-based water quality criteria regulations.

The following presents a brief discussion of the four development situations and the application of the performance based criteria:

*Development Situation 1* describes new low density development with a percent imperious cover of less than the average land cover condition (16% Chesapeake Bay watershed default value or a watershed specific value pre-determined by the locality).

**Note that the designation of the 16% impervious cover value is not intended to be a threshold for water quality compliance. Simply stated, a development with less than 16% impervious cover should be reviewed for the type and distribution of the impervious cover prior to determining that no water quality measures are required**.

A low density development with scattered disconnected impervious cover (such as lots sized at 1 acre or more) can easily be considered to have negligible impacts on water quality if the clearing and grading is limited to the minimum needed to build the road and site the houses (other considerations such as maintaining the natural stream buffers, avoiding steep slopes, and minimizing wetland impacts and tree removal should also be evaluated).

Some low impact development (LID) strategies recommend the clustering of development and the associated impervious cover and preserving open space. This strategy allows the overall impervious cover to be kept low while allowing for the preservation of high priority open space such as stream buffers and unmanaged open space. However, the clustered development represents a significant source of increased runoff and pollutant load when directly connected to the drainage system. Guidance on mitigating these impacts within the LID strategy can be found in the references provided at the end of this chapter.

If, on the other hand, the development consists of commercial or industrial development and associated infrastructure (parking lots, roads, and other impervious surfaces), located on a sufficiently large parcel such that the total area of impervious cover is less than 16%, and the improvements include a directly connected drainage network, then water quality controls should be provided. This type of development poses a very difficult development situation to regulate using the performance-based water quality criteria since the overall percent impervious cover is low. Initial efforts to define the impervious cover as connected or disconnected led to very awkward and subjective regulatory language. Another option considered revising the definition of *percent impervious* to read "the impervious area divided by the drainage area within the site multiplied by 100." Again, various development situations were presented which led to subjective interpretations of these definitions. The preferred method of dealing with this issue was determined to be clear guidance on the intent of the 16% impervious cover "average land cover condition," and a case by case evaluation of the application of the performance-based water quality criteria.

***When improvements on a site are concentrated such that the impervious area is collected and drained to a single receiving channel (connected impervious cover), it is reasonable to expect that the developed condition runoff will have an impact on the receiving system in terms of water quality impairments, regardless of the overall "site" percent imperviousness, and therefore should be considered in the water quality strategy. In such cases, DCR recommends that the percent impervious cover calculation be based on the drainage area being collected by the improved drainage system.***

*Development Situation 2* describes new development which results in impervious cover greater than the average land cover condition. The selection and location of a BMP to satisfy the pollutant removal requirement is verified using the Simple Method.

*Development Situation 3* describes development of a site with existing development already present. This development situation is provided to help create an incentive for development, or "redevelopment" of existing infrastructure as opposed to developing a raw piece of land. Clearly redevelopment contains more challenges with regard to existing utilities, building locations, entrances, drainage systems, etc. The requirement of 10% reduction in calculated pollutant load from the site allows flexibility in siting a BMP at the most advantageous location with regard to existing site restrictions. If the amount of impervious surface does not change significantly, the designer has the choice of several BMPs to achieve the 10% reduction including the Manufactured BMP Systems (**Minimum Standard 3.15**) which can be easily located on an existing storm system.

*Development situation 4* accounts for redevelopment where the existing development is served by an existing water quality BMP. This implies that the BMP was specifically designed to serve as a water quality BMP. In order for the existing BMP to satisfy the criteria it must be shown to have been designed and constructed properly and be in good working condition. New maintenance agreements may be necessary for continued operation of the BMP, as well as design enhancements, to ensure continued successful operation in the new development or redevelopment condition.

The performance-based water quality criteria allows the designer to locate the BMP at the most advantageous location on the site relative to the post-developed drainage divides, topography, etc, in order to meet the "pollutant removal" requirements of the four development situations. The pollutant removal requirements are based on the anticipated pollutant load from the site. Since a "site" may consist of several distinct drainage areas and discharge points, the designer must apply the removal efficiency of the BMP to the area draining to the BMP only. If this does not meet the removal requirement for the site, additional BMPs must be located in other drainage areas until the total pollutant removal satisfies the requirements, or a more efficient BMP should be selected. (All drainage discharges **are** subject to Erosion and Sediment Control Minimum Standard MS-19 - Channel Adequacy).

BMPs with the same pollutant removal mechanisms should not be located in series (runoff flowing from one BMP to the next) with removal efficiencies simply summed together. Consideration should be given to the form of pollutant which is targeted for removal. Sources cite that approximately 40% of phosphorus is bound to sediment or in particulate form. Thus BMPs added in series which serve to remove only particulates (settling) will not significantly increase the pollutant removal efficiency. While there may be some additional removal efficiency, the increase is certainly less than the algebraic sum of the two individual efficiencies.

The performance-based water quality criteria and calculation procedures should generally be applied to subdivision developments on a whole, and not to individual lots. This is not a contradiction to the previous discussion, however, there does appear to be a certain amount of judgement required to effectively comply with the intent of the water quality criteria. Many subdivision type developments can be effectively controlled with several BMPs serving individual lots or concentrated areas of impervious cover. The calculation procedure accounting for several BMPs may still be applied to the whole parcel or development in order to calculate the total pollutant removal achieved by the BMP strategy (the BMP strategy in this case includes multiple BMPs).

### 2. Technology-Based Water Quality Criteria

The selection of a BMP using the technology-based water quality criteria is based on the imperviousness and size of the drainage area. Review of **Table 2-3** reveals that each BMP is associated with a range of impervious cover. The development of a highly impervious land use such as an office park, in the range of 38 - 66% impervious cover, would indicate that an appropriate selection of BMP should be bio-retention basin or filter, extended detention-enhanced, retention basin II, or infiltration (or any of the BMPs listed for an imperviousness range of 67 - 100%).

Likewise the development of a low density subdivision in the range of 16 -21% imperviousness would indicate the selection of a vegetated filter strip or grassed swale (or any of the more efficient BMPs). The designer need only verify using the performance-based calculation procedure that the required removal efficiency would dictate a similar selection, thus indicating the equality of the two methodologies.

The difference in the two methodologies is the ability to incorporate a combination of BMPs using the performance-based criteria. Consider the just mentioned office park. If an extended detention-enhanced basin is selected, yet does not capture the runoff from the entire site to the effect that the calculated pollutant removal of the BMP does not satisfy the site or planning area pollutant removal requirement, then an additional BMP or a more efficient BMP must be designed.

Consider, as part of the office park, a two acre parking area along the edge of the office park which does not drain to the extended detention-enhanced facility. The designer may choose to incorporate a grassed swale with check dams to control the two acre drainage area. Since the two acre drainage area is almost entirely impervious, strict application of the technology-based criteria would preclude the use of anything but the most efficient BMPs (sand filter, infiltration, etc.) The performance-based criteria, on the other hand, allows for a total pollutant removal to be calculated to measure the combined effectiveness of the more efficient extended detention-enhanced facility on the majority of the site along with the lower efficiency grassed swale serving the small portion of the site.

The use of sound judgement in the application of multiple BMPs should dictate. If the designer is using the technology approach to control a majority of the site, and proposes a less efficient BMP to control the small area draining in the other direction, the requirement to calculate the total site pollutant removal using the performance-based calculation procedure is at the discretion of the plan approving authority. On the other hand, if a portion of the development site is being left uncontrolled, the plan approving authority may certainly require the performance-based calculation procedure to verify compliance.

Several examples will be provided by DCR as guidance in these types of review decisions.

## 2-4 REGIONAL STORMWATER MANAGEMENT PLANS

The development of a regional stormwater management plan allows a local government to strategically locate stormwater facilities to provide the most efficient control of localized flooding, stream channel erosion, and water quality. In addition, a regional plan provides the added benefit of mitigating the impacts of existing development to allow for restoration of urbanized stream systems.

The objective of a regional stormwater management plan is to address the stormwater management concerns in a given watershed with greater economy and efficiency by installing regional stormwater management facilities versus individual, site-specific facilities. The result will be fewer stormwater management facilities to design, build and maintain in the affected watershed. It is also anticipated that regional stormwater management facilities will not only help mitigate the impacts of new development, buy may also provide for the remediation of erosion, flooding or water quality problems caused by existing development within the given watershed.

If developed, a regional plan shall, at a minimum, address the following:

1. The specific stormwater management issues within the targeted watershed.

2. The technical criteria in 4VAC3-20-50 through 4 VAC 3-20-85 as needed based on number 1 above.

3. The implications of any local comprehensive plans, zoning requirements and other planning documents.

4. Opportunities for financing a watershed plan through cost sharing with neighboring agencies or localities, implementation of regional stormwater utility fees, etc.

5. Maintenance of the selected stormwater management facilities.

6. Future expansion of the selected stormwater management facilities in the event that development exceeds the anticipated level.

The benefits of regional stormwater management plans are well documented by those localities which have implemented them. Likewise, adverse impacts are also documented. The debate over the merits of regional facilities versus the impacts is different in each watershed. The following provides a list of some of the more common issues frequently surrounding the decision making process. Future guidance, in conjunction with the Corps of Engineers and the Department of Environmental Quality, will be provided by DCR.

Asserted problems with on-site facilities:

1. Not as efficient at pollutant removal as larger facilities.

2. More land is disturbed because of need for a number of smaller facilities; an additional 5 to 10 acres will not be available for development out of every 1, 000 acres served by stormwater management facilities.

3. Not well maintained, reducing pollutant removal efficiency.

4. More complicated for localities to maintain a large number of small facilities.

5. Access may be more difficult.

6. Do not typically have maintenance features such as forebays, access roads, and sediment disposal areas. Difficulty in access and maintenance often results in maintenance responsibility being shifted to homeowner's associations, which experience has shown, are not generally capable of coordinating the public works function required to effectively maintain stormwater management facilities. Uncertainty of maintenance puts long- term reliability of the facility in question.

7. Pose a greater public safety hazard.

8. Have more potential to become "eyesores."

9. Can only be sited to address stormwater discharges from future development since they are implemented for individual development projects only.

10. More expensive.

11. May result in a haphazard siting pattern for stormwater management facilities; with only limited control of down stream erosion and flooding.

Asserted benefits of regional facilities:

1. More efficient and ensure the highest possible efficiencies for the entire watershed, rather than one small site.

2. Offer the ability to control temperature of outflow which is not possible with small facilities.

3. Can be strategically located within a watershed and designed for coincident stormwater releases,

resulting in a coordinated system of controls.[1]

4. Can be located to control some existing, as well as future, development and can compensate for pre-existing development that does not have adequate (or any) stormwater control to help reduce stream bank erosion and negative impacts to downstream floodplains and wetlands.

5. More likely to be adequately maintained.

6. Lower lifetime maintenance cost; more easily accessed and maintained.

7. Provide a recreational amenity.

Asserted adverse consequences that may result from regional facilities:

1. Reaches of a stream above an instream facility receive untreated stormwater containing a variety of pollutants that adversely impact water quality and stream habitat.

2. Upstream inundation from the pond's impounded water destroys floodplains, wetlands and stream habitats.

3. Changes in water depth and frequency and duration of flooding can change the plant communities above and below the pond.

4. Wet ponds block the passage of fish and other aquatic life that normally move up and down the stream and disrupt the downstream movement of food particles, which are the base of the food chain for stream ecosystems.

5. The hydrologic change caused by the impoundment will eliminate species that thrive on flowing stream conditions, but cannot tolerate ponded conditions.

6. Water temperature increases in the pond, as well as downstream, due to incoming runoff can eliminate certain species of fish and aquatic insects.

7. Are more likely to be located in and adversely impact wetlands.

8. Large regional facilities are more difficult to administer because the locality must (1) prepare

[1] Peak flow reductions are only localized in nature because of several factors: The small drainage area controlled by each facility; the extended duration over which the facility releases stormwater flows; the relatively high peak release rates from the on-site facilities (compared to regional facilities which can be sized to achieve release rates that are much less than pre-development conditions); and interactions among releases from on-site facilities which are not coordinated.

a master plan specifying the sites and design criteria, (2) implement a phased construction program so that facilities are in place when new development occurs, and (3) recover pro-rata charges from new development or establish a stormwater utility with which to offset the costs for the regional facilities.

## 2-5 COMPREHENSIVE WATERSHED MANAGEMENT

The 1994 General Assembly passed Senate Joint Resolution (SJR) No. 44 which allowed for the continued study of the efficiency and consistency of the stormwater management and permitting policies of the Commonwealth. The resolution included, among other elements, the study of approaches to watershed management of stormwater. The following incorporates the findings of the Technical Task Force of the SJR 44 Joint Study Committee.

A comprehensive watershed management plan is the result of studying the environmental and land use features of a watershed to identify those areas that should be protected and preserved and stormwater management measures and design criteria to be utilized to protect such areas so that development, when it does occur, will not negatively impact water resources. In so doing, watershed planning uses and protects ecological processes to lessen the need for structural control methods that require capital costs and maintenance. By including consideration of the watershed and its characteristics, cumulative impacts and inter-jurisdictional issues are more effectively managed than when solely relying on a single site permit approach. Watershed planning can be an important tool for maintaining environmental integrity and economic development.

The Stormwater Management Act (§10.1 - 603.1 et. seq. of the Code of Virginia) enables localities to adopt more stringent stormwater management criteria than those promulgated in the Stormwater Management Regulations (4VAC3-20), provided that the more stringent regulations are based upon the findings of local comprehensive watershed management studies.

Historically, a watershed or regional plan simply focused on the implementation of regional stormwater management facilities within a designated watershed. As our understanding of the dynamic relationship between development and water resources grows, so should the goals of a watershed plan. A watershed plan should provide:

- guidance as to the areas and resources to avoid and protect,
- development guidelines to minimize the impacts of new development on water resources,
- identification of retrofit opportunities such as BMP retrofits, stream restoration, etc. to mitigate impacts resulting from existing development, and
- appropriate stormwater management options (structural and non-structural) including design criteria and locations.

To accomplish these goals, a watershed plan should consist of three components: **Inventory, Planning, and Implementation.**

These three components include the following:

**A. Inventory**

1. **Define the watershed boundary.**
2. **Conduct a watershed inventory of natural resource features** (wetlands, floodplains, stream corridors, greenways, rare and endangered species, steep slopes, erodible soils, karst bedrock areas, sensitive habitats, fish and wildlife resources, recreational areas, sources of water supply).
3. **Conduct a stream inventory** (size, order, water and habitat quality, flow regime).
4. **Identify significant environmental features in neighboring watersheds** (large pollution sources, wildlife refuges, sources of water supply).
5. **Identify and quantify existing sources of point and nonpoint source pollution.**
6. **Model the existing hydrology and hydraulics of the watershed** (understand the impact of land use, conveyances, land cover, stormwater management facilities, stream cross sections, roadway crossings, flooding and drainage problems).

**B. Planning**

1. **Define the goals of the watershed management plan** (what is envisioned for the watershed and who is going to lead the implementation efforts).
2. **Identify and quantify future sources of point and nonpoint source pollution.**
3. **Model the future hydrology and hydraulics of the watershed.**
4. **Develop and evaluate alternatives to meet the goals and manage water quality** (point and nonpoint source pollution) **and quantity** (hydrology and hydraulics).
5. **Identify opportunities to restore natural resources.**
6. **Develop the watershed management plan** (include specific recommendations on development and land use evaluation, selection of structural and non-structural BMPs, public education needs, regulatory requirements, and funding).

**C. Implementation**

1. **Identify the stakeholders responsible for developing, implementing and updating the plan to ensure long-term accountability.**
2. **Define the implementation costs** (capital costs and annual administrative, operations and maintenance costs) **and who will pay for the implementation of the watershed management plan** (provide incentives and secure commitments).
3. **Develop a watershed monitoring program.**
4. **Develop an evaluation and revision process for the watershed management plan.**
5. **Establish and implementation schedule.**

The process described in the following sections is based on the above mentioned steps and can be used to develop a watershed management plan for any watershed. The amount of effort expended on each step depends on the specific goals of the project, the data available, and the people involved in preparing and implementing the plan. Some of the steps need to be conducted concurrently to facilitate a successful implementation of the plan.

### 2-5.1 Inventory of Watershed Characteristics

The inventory of the watershed characteristics will serve as the basis for the design and location of BMPs at the regional (watershed) level and flood/erosion controls. The inventory data will be integrated with information from the planning and implementation components to develop the watershed management plan.

**1. Define the Watershed Boundary**

In order to develop a meaningful and implementable watershed management plan, an appropriate watershed or subwatershed needs to be selected. Watershed plans often end up on the shelf because the size of the watershed was too large (greater than 60 square miles) and the focus of the plans became too fuzzy (Center for Watershed Protection, 1996). In addition, the impacts of different land uses on the watershed hydrology, stream health and water quality is difficult to evaluate, unless very detailed models are developed.

Municipalities can be subdivided into watersheds or subwatersheds ranging from 2 to 20 square miles in drainage area. When these watershed or subwatersheds extend beyond the municipality's corporate limits, efforts should be made to develop memoranda of understanding with adjacent jurisdictions to facilitate and promote implementation of watershed management plans. Once the watershed or subwatersheds are delineated, the municipality can prioritize the development of watershed management plans based on local needs and water quality and quantity criteria.

**2. Conduct a Watershed Inventory of Natural Resource Features**

Successful implementation of a watershed management plan will also depend on the ability to obtain the appropriate permits from state and federal agencies. An inventory of natural resource features in the watershed will promote the development of a BMP siting approach that minimizes or avoids impacts on environmental resources to the maximum extent practicable. This BMP siting approach will facilitate permitting.

The natural resource features to be inventoried would depend on the characteristics of the watershed being studied and could include:

- Wetlands
- Floodplains
- Stream corridors and greenways
- Steep slopes
- Erodible soils
- Karst bedrock areas
- Rare and endangered species
- Sensitive habitats
- Cultural resources
- Fish and wildlife resources
- Recreational areas
- Sources of water supply

Wetlands

Wetlands provide unique habitats for both plants and wildlife, including many threatened and endangered species. As a consequence, wetlands are valued for aesthetic and recreational reasons. Wetlands also provide valuable flood storage, groundwater recharge, and pollutant-filtering functions.

Wetlands are widely scattered throughout Virginia and commonly are encountered on development sites and throughout watersheds. Protecting the natural functions of wetlands is a critical element of the site development process and watershed management planning. For moderate- to high-quality wetlands, which are very difficult to replace, avoidance is recommended. If the watershed contains scattered, small, low-quality wetlands, which are more readily replaced, mitigating the wetlands at a central location may be more appropriate, thereby enhancing wetland functions and reducing a potential constraint to development. Early coordination with resource agencies is recommended.

Floodplains and Stream Corridors

Floodplains and stream corridors include waterways and adjacent riparian lands that may be subject to flooding. Natural waterways provide habitat for fish, aquatic plants, and benthic (bottom dwelling) organisms. Development in waterways may destroy aquatic organisms and introduce large loads of sediment and pollutants into the waterways. Modifying waterways to accommodate development also may destroy the physical features essential to a good habitat, including: stable stream banks and bottom substrates, pools and riffles, meanders, and spawning areas.

Vegetated riparian land adjacent to streams stabilizes the stream bank, filters pollutants from storms and floods, and provides habitats for a variety of amphibians, aquatic birds, and mammals that depend on the proximity to water for their life functions. Development in floodplains and riparian corridors can impair the functions and subject structures to damage from flooding and the meandering of natural streams.

A filter strip or riparian-forested buffer should be preserved or created along the banks of streams, where possible. Furthermore, consideration should be given to establishing setbacks for intensive development (e.g., buildings, parking lots, roadways). This will minimize the potential for sediment releases to the streams, as well as maintain the corridor to achieve flood control, water quality, and habitat enhancement objectives. If a development site contains a highly channelized stream, the best interest of both the developer and the aquatic resource may be served by restoring the stream corridor.

Shorelines of ponds, lakes, and wetlands provide many of the same functions as riparian stream corridors provide for streams. Stable vegetated shorelines are particularly valuable in preventing erosion caused by wave action. Protection of shorelines should be considered when developing water dependent development, such as piers and marinas (CH2M HILL, 1998).

Steep Slopes and Highly Erodible Soils

From an erodibility standpoint, the definition of steep can vary depending on surface soil type and underlying geology. In general, extra caution is warranted on a slope exceeding 10 percent (1 foot of vertical drop per 10 feet of horizontal distance). However, even flatter slopes that have soil classified as highly erodible should be identified as steep.

Disturbing steep slopes with development causes instability of the soil on the slopes. Inappropriate development destroys vegetation, root systems, and soil structures. High runoff velocities from exposed steep slopes result in destructive and unsightly erosion, denuded slopes that may be difficult to revegetate, and sediment deposition in sensitive areas both on and off the site.

A general rule to be followed in site development is to minimize the area and time of disturbance and to fit the development to the natural terrain. Stabilizing vegetation should be protected to the maximum extent practicable and disturbed areas should be immediately revegetated. Extending this general rule to the entire watershed will promote preservation of natural resource features.

Karst Bedrock Areas

Karst bedrock areas are underlain by bedrock containing soluble minerals. Karst areas develop voids and solution channels as groundwater gradually dissolves the bedrock. In these terrains groundwater flow can be extremely rapid and unpredictable. Furthermore, the concentration of runoff may stimulate the formation of sinkholes. Sinkholes can develop as flowing water exposes and then washes into the mouths of the near surface openings of subterrain channels and caverns. Rapid degradation of groundwater resources can result when sediment or pollutant laden runoff percolates into karst bedrock aquifers.

Several areas of Virginia are underlain by limestone, dolomite, or marl carbonate rocks which are potentially susceptible to the development of karst conditions. Before introducing site alterations that could concentrate or pond runoff, the presence or absence of carbonate bedrock should be established. If carbonate rocks do occur a professional geologist or civil engineer should be consulted to determine whether sink hole activity is likely. The United States Geological Survey is a good source of information on karst bedrock in Virginia. If an area is prone to sink hole development, site drainage should be planned to minimize the concentration of runoff. This can be accomplished by reducing the hydraulic connectivity of impervious surfaces and by the use of filter strips. Where they are required, channels or ponds should be lined.

Certain BMPs can be used in karst areas to provide infiltration opportunities over a very large area. Examples are filter strips, large bioretention facilities, and permeable pavement. These practices mimic the natural process by which rainfall enters the subsurface. Point sources of infiltration, such infiltration trenches or dry wells should be avoided (CH2M HILL, 1998).

Threatened and Endangered Species

Existing information can be obtained from surveys conducted by the Division of Natural Heritage (DNH) of the Virginia Department of Conservation and Recreation. For portions of the watershed that have not been previously surveyed, DNH's Element List can be compared to plant community information derived from previous investigations in the watershed, as well as from wetlands identification efforts. The inventory should include a list of potential threatened or endangered species.

Cultural Resources

Existing information can be obtained from the Virginia Department of Historic Resources. For potential regional (watershed) BMP sites, background research to characterize the cultural resource potential of the project area can be conducted. This research will provide a historic context for evaluating any cultural resources that might be located in the project area.

Fish and Wildlife Resources

Existing information can be obtained from the Virginia Department of Game and Inland Fisheries. This information will be useful when defining watershed goals and selecting BMPs to protect sensitive areas. In addition, fish can be a good indicator of stream health and can be used during the evaluation of effectiveness of the watershed management plan, as part of a watershed monitoring program.

Recreational Areas and Sources of Water Supply

An inventory of recreational areas and sources of water supply will also facilitate, and in some cases mandate, the goals of the watershed. This information will also be important in the selection of models that will be needed to identify sources of pollution, understand the hydrologic and hydraulic characteristics of the watershed, and evaluate alternatives to meet the watershed goals and manage water quality.

**3. Conduct a Stream Inventory**

Classifying the stream system within a watershed will further the understanding of its characteristics and will provide a framework for evaluating alternatives. Streams within a watershed can be inventoried based on size, order, water and habitat quality, or flow regime.

**4. Identify significant environmental features in neighboring watersheds**

Each subwatershed is nested within many larger watersheds. Therefore, watershed management plans for smaller watershed have to be developed within the context of the larger watershed in which they are located. Once the larger and neighboring watersheds are identified, the goals of those watersheds can be incorporated in the watershed management plan. Some of the goals that typically are incorporated in local watershed management plans include nutrient and toxic targets, such as the Tributary Strategy targets, water supply, flood protection, and waste water requirements or effluent limits (Center for Watershed Protection, 1996). In addition, large pollution sources, wildlife refuges, and sources of water supply in neighboring watersheds may also provide additional goals for the watershed management plan.

**5. Identify and Quantify Existing Sources of Point and Nonpoint Source Pollution**

Existing information on point sources of pollution can be obtained from the Virginia Department of Environmental Quality (DEQ). Typically, the NPDES permits for point sources will also include some monitoring requirements that can provide additional information for the watershed management efforts. Nonpoint source data can be obtained from DCR and from the local Soil and Water Conservation Districts. The local public works or engineering office can also be good sources of information on previous studies and monitoring efforts.

Watershed models are tools used to understand the cause-and-effect relationships within a watershed. Specifically, water quality models provide information on pollutant loads (from point and nonpoint sources) and their movement throughout the watershed.

Model selection is a function of the following variables:

- The goals and objectives of the watershed management plan
- The data available to describe the hydrologic and hydraulic characteristics and water quality problems in the watershed
- The regulatory requirements and other watershed specific environmental and water quality issues (including time and space scales of the issues or problems)
- The resources (cost, time, hardware and software, modeling expertise, funds) available for applying the model and implementing the recommendations developed with the model

The objectives of the model application for a watershed management plan may range from simple screening of environmental problems that require minimum data input to detailed analysis of water quantity and quality in the watershed. Detailed analysis requires more input data and usually provides information needed for the design of a specific project or for the analysis and solution of specific environmental problems. Detailed analyses are used to represent the watershed processes that affect pollution generation. However, it is not always true that detailed analyses, based on sophisticated models, provide the most accurate representation of the watershed and its environmental problems; it is best to use the least complicated model that will produce the results for appropriate decision making.

Model selection also depends significantly on the data available in the watershed. The precision of the model predictions is affected by dynamic and transient conditions, high spatial variability (mainly related to rainfall variability and land use), and differences in event conditions (such as antecedent moisture conditions, infiltration potential, local pipe or stream conditions, etc.). The data availability and the simulation complexities affect model selection by tempering the decision towards acceptance of a model that is accurate but not as precise as other more sophisticated models.
In addition to data availability issues, monitoring data and watershed responses can be highly variable. Selecting a simpler model, and accepting results that are not as precise as desired but remain accurate, is an appropriate strategy.

### 6. Model the Existing Hydrology and Hydraulics of the Watershed

The model selection strategy presented in the previous section also applies to hydrologic and hydraulic models.

Hydrologic models provide information on the amount of runoff that will reach the outlet of the watershed and any receiving waters. Hydraulic models estimate water surface elevations and velocities of surface water. These models are also used to characterize the drainage system in the watershed. Groundwater models represent the movement of groundwater.

The focus of the modeling of the existing characteristics of the watershed is to develop baseline information that will be used to evaluate BMP siting and sizing alternatives for meeting the watershed goals and solving drainage and flooding problems. The hydrologic and hydraulic models will also facilitate the understanding of the impact of land use, conveyances, land cover, stormwater management facilities, stream cross sections, roadway crossings, and flooding and drainage problems.

Accurate land use data will ensure accurate modeling results. Developing an updating land use and impervious cover information will facilitate the implementation of the watershed plan.

### 2-5.2 Planning and Developing the Watershed Management Plan

This second component will define the goals for the watershed management plan; will model future characteristics of the watershed; will develop alternatives to restore resources and meet the goals, including BMPs at the regional (watershed) level; and will produce the watershed management plan. The inventory data developed in the first component will be used as part of the decision-making process illustrated in this component.

#### 1. Define the Goals of the Watershed Management Plan

The first step of the planning component is to define the goals that are most important to the watershed to be protected and to the stakeholder group that will be defined as part of the third component, implementation. As previously mentioned, some of the steps of the three components (inventory, planning, and implementation) need to be conducted concurrently.

A stakeholder group beginning a watershed effort needs to determine what it wants to accomplish and how it wants to use the water body being protected (water quality enhancements and quantity control). The clearer the goals, the easier it is to track progress towards meeting those goals. The goals tend to become clearer as the stakeholders proceed in their efforts. Therefore, the planning process should allow for a systematic re-evaluation of the goals at least every 3 to 5 years.

If possible, express the goals of the watershed management plan in terms of the condition of the waterbody relative to its beneficial uses, not in terms of achieving a certain level of pollutant reduction or applying a certain technology.

#### 2. Identify and Quantify Future Sources of Point and Nonpoint Source Pollution

This step involves using the water quality models developed in the inventory component (**Section 2-5.1, step 5**) and modifying them to include future development conditions in the watershed. It is important to use future land-use information from the comprehensive plan of the municipality and any amendments or recent rezoning cases.

#### 3. Model the Future Hydrology and Hydraulics of the Watershed

This step involves using the hydrologic and hydraulic models described in the inventory component (**Section 2-5.1, step 5**) and modifying them to include future development conditions in the watershed. It is important to use future-land use information from the comprehensive plan of the municipality and any amendments or recent rezoning cases.

**4. Develop and Evaluate Alternatives to Meet the Goals and Manage Water Quality and Quantity**

In order to meet the watershed goals and to solve the watershed's problems effectively, the watershed master plan should consider all feasible alternatives. These alternatives will manage water quantity and quality in the watershed. Therefore, the alternatives will address flooding, drainage, erosion, and stormwater pollution problems.

Generally, alternative solutions mitigate **flooding and drainage damages** by providing additional storage of flows, by increasing the conveyance capacity of the drainage and stream system, or by floodproofing structures at risk of flooding. Alternative solutions mitigate **erosion damages** by stabilizing stream banks using non-erosive materials and/or by redefining the meandering pattern and using the channel and floodplain to dissipate the flow energy. Alternative solutions mitigate **stormwater pollution** problems by providing structural and non-structural BMPs.

Alternatives should be evaluated by using the existing and future condition models and the information from the inventory component described in **Section 2-5.1**. A map of the watershed showing the recommended alternatives should be prepared and distributed to all stakeholders.

Each alternative, or combination of alternatives, also could be evaluated according to screening criteria that address technical, practical, environmental, economic, and political feasibility. Alternatives can be investigated in detail when they appeared to have potential to be cost-effective and satisfy all project criteria.

Selecting sites for regional (watershed-level) BMPs or flood/erosion controls involves balancing pollutant removal, runoff attenuation, environmental permitting constraints, and cost issues. The following is a typical sequence of the iterative process to be completed for each of the potential sites:

A. Identify potential regional BMP sites and sites for flood/erosion controls.

B. Field screen the sites taking into account the following:
   - drainage area
   - topography
   - existing development and projected future development
   - access and construction issues
   - wetlands constraints
   - other regulatory constraints
   - land ownership/value issues

C. Use the previously described watershed models to analyze pollutant reduction (phosphorous and total suspended solids management), flood/erosion control, and resource protection.

D. Use the inventory and models to identify performance standards for the selection, design, and location of BMPs and for the establishment of erosion, sedimentation, and flood control requirements.

**5. Identify Opportunities to Restore Natural Resources**

Protecting natural resources and drainage features, particularly vegetated drainage swales and channels, is desirable because of their ability to infiltrate and attenuate flows and to filter pollutants. However, this goal is often not accomplished in most developments. In fact, commonly held drainage philosophy encourages just the opposite pattern. Streets and adjacent storm sewers typically are located in the natural headwater valleys and swales, thereby replacing natural drainage functions with a completely impervious system. Runoff and pollutants generated from impervious surfaces flow directly into storm sewers with no opportunity for attenuation, infiltration, or filtration.
One method of preserving natural drainage features is to use *cluster development* to avoid disturbing major swales. Another recommended approach is to develop site plans that keep roads and parking areas higher in the landscape and *locate existing swales along back lot lines* within drainage easements.

**6. Develop the Watershed Management Plan**

The watershed management plan will integrate and summarize the different steps described in **Sections 2.5.1** and **2-5.2**. The plan needs to be succinct and simple to ensure that people read it. The plan needs to address the goals and problems of the watershed and should provide recommendations that are specific and implementable. Finally, the plan should include a budget and an implementation schedule, as described in **Section 2-5.3**, below.

### 2-5.3 Implementation of the Watershed Management Plan

A watershed management plan is effective if it is implemented. Implementation depends on the level of buy-in of the plan from the stakeholders. Stakeholders will remain interested if they are involved from the beginning and they have ways of monitoring the success of the plan.

**1. Identify the stakeholders responsible for developing, implementing and updating the plan**

Assemble stakeholders who are most affected early in the process. Specifically include those who use, impact and regulate the affected waterbody, and allow them to shape key decisions. Early and effective stakeholder involvement will ensure long-term accountability.

**2. Define the implementation costs and who will pay for the implementation of the watershed management plan**

Use uniform and consistent procedures to estimate project costs for the alternatives developed to solve the problems in each watershed. The cost should include capital costs and annual administrative, operations and maintenance costs for all the elements of the plan.

Identify the funding sources for implementation of the watershed management plan. Below is a summary of the possible funding sources:

- General obligation and revenue bonds
- Stormwater utility fees
- Land development fees
- Pro-rata share contributions
- General fund resources
- Loans and grant programs
- Special service districts and watershed improvement districts

**3. Develop a watershed monitoring program**

Develop a monitoring program that enables the stakeholders to objectively measure and track indicators of the watershed management plan's success. The indicators should focus on water quantity and quality issues, programmatic and socioeconomic needs, and physical and hydrologic measures.

Stormwater chemistry is fairly well understood. Therefore, chemical monitoring of stormwater outfalls will not necessarily provide valuable data. On the other hand, physical and biological monitoring and selected long-term stream monitoring stations will provide valuable information to "measure" the successful implementation of the watershed plan. If success is not achieved, the monitoring program will provide the data to make revisions to the plan. The monitoring program also will provide information to re-evaluate the watershed goals and the implementation schedule.

**4. Develop an evaluation and revision process for the watershed management plan**

During the implementation of the watershed management plan, it is likely that at least one of the following problems will occur:

- Monitoring indicates that the wrong problem is being solved.
- Solving one problem unmasks another problem that is more difficult to control.
- The program reaches some program or activity goals but may not be effective enough to reach the water

quality goals.

- Quantifiable objectives (e.g., pollutant load reduction or flood protection for specific storms) were set too low to solve the problem.

These unpleasant realizations typically occur because of data gaps during the development of the plan. Therefore, the watershed plan needs to include evaluation periods where aspects of the program can be revised if necessary. Watershed plan evaluations can take place every 3 to 5 years.

**5. Establish and implementation schedule**

Each of the steps presented in the previous sections represent groups of specific activities that make up the watershed plan. Because of the complex and developing nature of the plan, the implementation of the individual steps will occur over differing time frames and will not necessarily follow in a linear sequence but rather be in a parallel sequence.

Some activities need to be implemented quickly to ensure protection of the watershed others will take more time. Therefore, an implementation schedule typically includes a combination of immediate, short-term, and longer-term actions.

Implementation schedules need to be updated and distributed to all stakeholders regularly.

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*MINIMUM STANDARD 3.01*

# EARTHEN EMBANKMENT

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.01

# EARTHEN EMBANKMENT

### Definition

An earthen embankment is a raised impounding structure made from compacted soil.

### Purpose

The purpose of an earthen embankment is to impound stormwater runoff.

### Conditions Where Practice Applies

An earthen embankment is appropriate for use with infiltration, detention, extended-detention or retention facilities.

The design procedures presented in this section **may not** apply to small embankments or to storm drainage outfall structures with less than 3 feet of embankment height. The review and approval of such structures should be based on sound engineering practices and supporting calculations that verify a stable outfall for the 10-year storm, at a minimum.

Similarly, this section **does not** apply to embankments with a height of 25 feet or more and a maximum storage capacity of 50 acre-feet or more, as measured from the top of the embankment. Such structures may be regulated under the Virginia Dam Safety Act and the Virginia Dam Safety Regulations (VR 625-01-00).

The *height of an earthen embankment* is the vertical distance from the natural bed of the stream or watercourse, measured at the downstream toe of the embankment, to the top of the embankment. If the embankment does not span a stream or watercourse, the height is the vertical distance between the lowest elevation, measured at the outside limit of the embankment, and the top of the embankment.

## Planning Considerations

Earthen embankments are complex structures that must be designed and constructed with consideration given to the following: a) *specific site and foundation conditions*, b) *construction material characteristics*, c) *purpose of the impoundment*, and d) *hazard potential associated with the particular site and/or impoundment*.

The *hazard potential* associated with an impoundment is defined in the Virginia Dam Safety Regulations. It is based on the potential for loss of life and/or economic loss due to facility failure. While stormwater management embankments are typically much smaller than those regulated under the Virginia Dam Safety Program, the potential for significant property damage and loss of life may still be present. The engineer is responsible for analyzing potential downstream impacts and for determining if more stringent analyses are required. **Minimum** guidelines for those facilities **not covered** under Virginia's Dam Safety Regulations are provided in this handbook.

### Embankment Types

The type of embankment selected will depend on the purpose of the stormwater facility (detention, extended-detention, retention, etc.) and the available soil material for construction. The two general types are listed below:

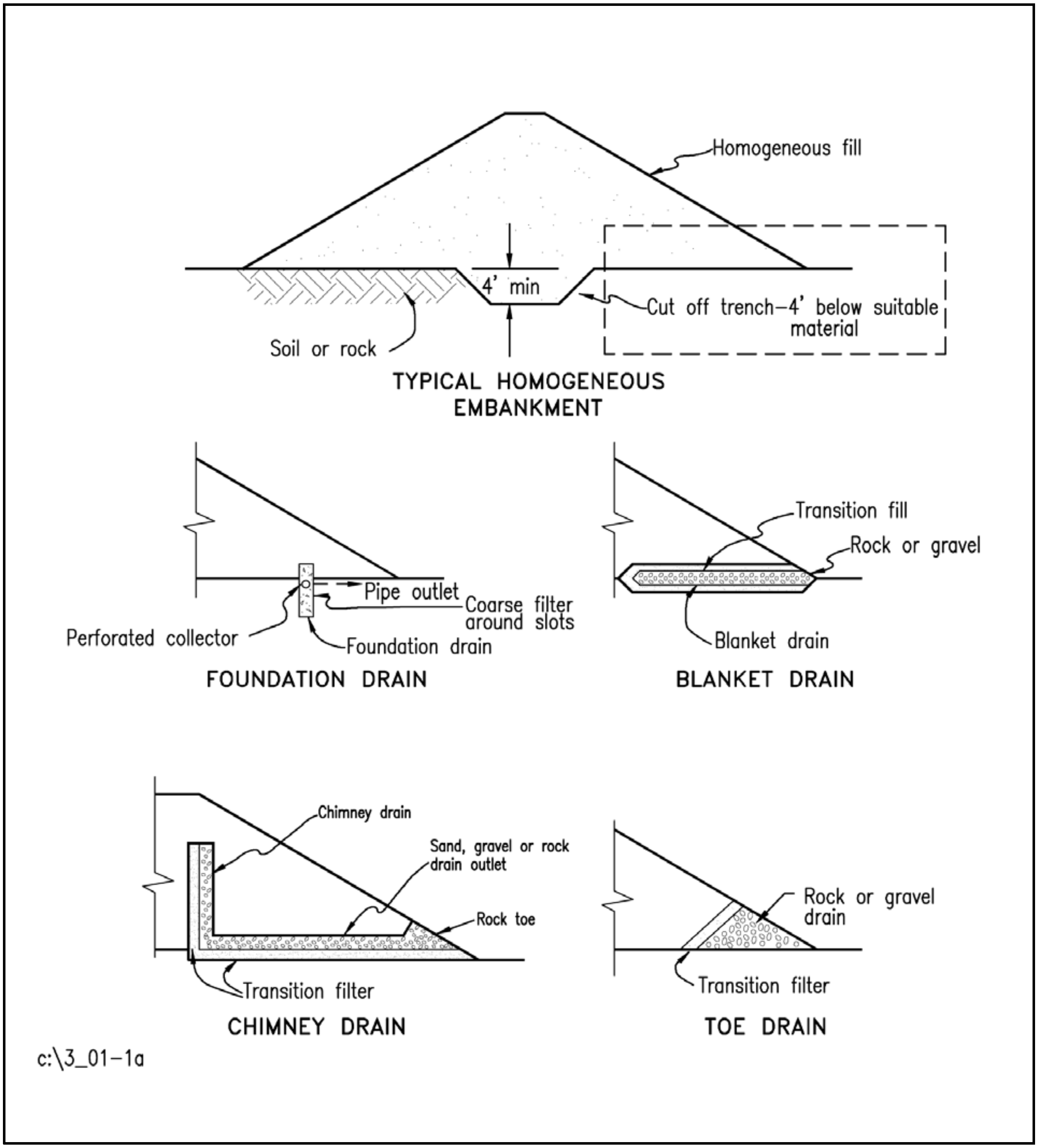
1. A *homogeneous embankment* is composed of one kind of material (excluding slope protection). The material used must be sufficiently impervious to provide an adequate water barrier, and the slopes must be moderately flat for stability and ease of maintenance (see **Figure 3.01-1a**).

2. A *zoned embankment* contains a central impervious core, flanked by zones of more pervious material, called shells. These pervious zones or shells enclose, support, and protect the impervious core. Typically, a zoned embankment requires an internal drain, or filter, between the impervious zone and the downstream shell and between the shell and the foundation (see **Figure 3.01-1b**.

### Soils Investigation

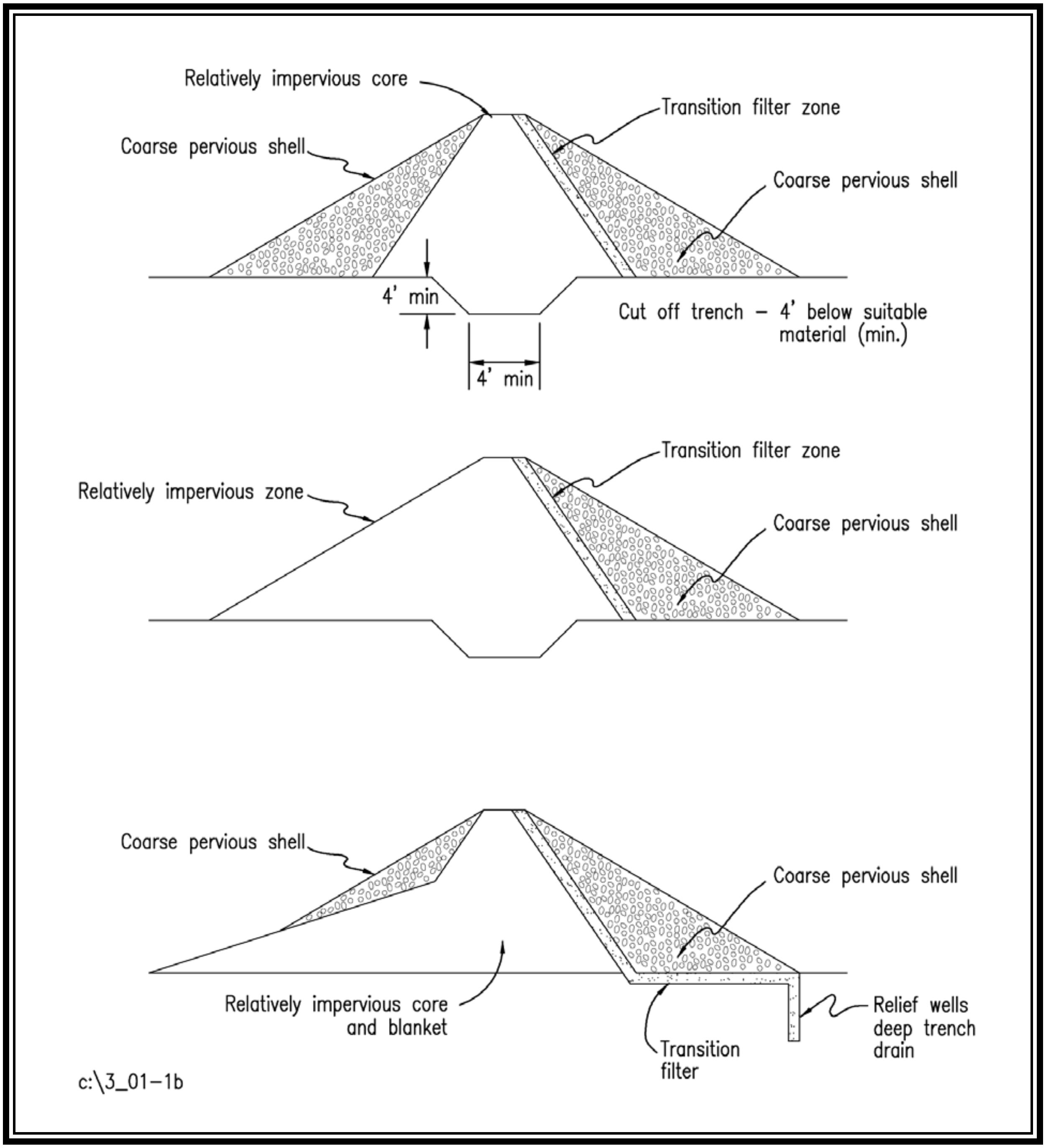
A soils investigation, or geotechnical study, should be completed before designing any earthen embankment covered in this section. The scope of such a study will vary from site to site based upon the size of each project. Recommended minimum guidelines for a geotechnical study are provided below. Refer to U.S. Department of Interior (USDI), Design of Small Dams, latest edition, for additional information.

**FIGURE 3.01 - 1a**
***Homogeneous Embankments w/ Seepage Controls***




*Source: SCS Engineering Field Manual*

**FIGURE 3.01 - 1b**
*Zoned Embankment*



Geotechnical Guidelines

The following discussion presents minimum recommended criteria for the planning and design of earthen embankments. The designer is responsible for determining which of the guidelines are applicable to the specific project and for determining if any additional investigations are required.

The validity of the design depends on the thoroughness of the site investigation, the adequacy of the testing program, and the soundness of the designer's judgment. Design components based on quantitative soil tests, such as analyses of slope stability, seepage, and settlement, are not discussed herein, but they are necessary to design large dams. Such analyses will logically follow the selection of a preliminary design. Even for small earth dams that have a low hazard potential, the following criteria should be considered in a geotechnical report.

*A geotechnical engineering study should evaluate the stability of the proposed embankment.*

A geotechnical engineering study should consist of 1) *a site investigation*, 2) *laboratory testing*, and 3) *an engineering analysis*.

1. A field investigation should include the review of available soils information and a subsurface exploration. Test borings, test pits, or both, should be used to evaluate the foundations, abutments, borrow materials, reservoir area, embankment design and any other pertinent geological considerations. In areas underlain by Karst limestone, a subsurface profile using seismic or sonar technology should be considered to verify that subsurface anomalies do not exist. This type of subsurface investigation may also be recommended in areas known to have been previously mined for mineral extractions.

2. Laboratory testing should be completed to evaluate the various soils. At a minimum, an *index property test* should be completed to classify the soils following the Unified Soil Classification System. Shear strength, compressibility, and permeability testing may be required depending upon the size and complexity of the embankment and the nature of the site's subsurface conditions.

3. A geotechnical engineer should do an engineering analysis and present his or her findings, recommendations and comments on items such as: foundation materials and preparation; design of interior drainage features and filters; and geotechnical design of conduits/structures through the embankment, including seepage and stability analyses. The engineer should also provide a summary describing the soil types and rock strata encountered and explaining the laboratory tests and their results.

Stream Diversions

The design of some earthen embankments will require provisions for stream diversions around or through the embankment site during construction. A stream diversion can be accomplished by a variety of acceptable means, including open channels, conduits, coffer dams, and pumping. Occasionally, stream diversions may be required to meet additional requirements and/or to be permitted by agencies such as the U.S. Army Corps of Engineers, the Virginia Department of Environmental Quality, and/or the Virginia Marine Resources Commission. Refer to the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition, for additional guidance on stream diversions.

## Design Criteria

To establish *design water surface elevations* and *spillway capacity* for earthen embankments, various hydrologic design methods and spillway storm frequencies may be used. Factors that affect their selection include: a) *the purpose of the stormwater facility: flood control, water quality enhancement*, *and/or channel erosion control,* b) *the contributing watershed size*, and c) *local regulations*. Despite the design method selected or the frequency storm is used, **the embankment should always be analyzed to ensure safe passage of the maximum spillway design storm while maintaining its structural integrity and stability**. Furthermore, the embankment height should be set such that runoff from the spillway design storm can safely pass through one of the following spillways without overtopping the embankment:

- a natural or constructed spillway,
- a principal spillway, or
- a combination of a principal spillway and an emergency spillway.

Hydrologic and hydraulic methods are described in **Chapters 4** and **5**, respectively.

Local ordinances or watershed conditions may require a more stringent analysis of the embankment concerning overtopping or spillway capacity. The Soil Conservation Service's (SCS) National Engineering Handbook and the Virginia Dam Safety Regulations provide a classification of dams based on the *potential hazard* from failure. A dam failure analysis, or *breach analysis*, may be required to learn the extent of the potential hazard. Any dam breach analysis should use a method similar to the Army Corps of Engineers, SCS (TR-60), National Weather Service, or that specified by the local authority.

Embankment Stability

An earthen embankment must be designed to be stable against any *force condition* or combination of *force conditions* that may develop during the life of the structure. Other than overtopping caused by inadequate spillway capacity, the three most critical conditions that may cause failure of the embankment are:

1. *Differential settlement* within the embankment or its foundation due to a variation in materials, a variation in embankment height, or compression of the foundation strata. Differential settlement may, subsequently, cause the formation of cracks through the embankment that are roughly parallel to the abutments. These cracks may concentrate seepage through the dam and lead to failure by internal erosion.

2. S*eepage* through the embankment and foundation. This condition may cause piping within the embankment or the foundation, or both.

3. S*hearing stresses* within the embankment and foundation due to the weight of the fill. If the shearing stress force exceeds the strength of the materials, sliding of the embankment or its foundation may occur, resulting in the displacement of large portions of the embankment.

The stability of an embankment and its side slopes is dependent on the following: 1) *construction materials*, 2) *foundation conditions*, 3) *embankment height and cross-section geometry*, 4) *normal and maximum pool levels*, and 5) *purpose of BMP: retention, detention, or extended-detention*. The embankment cross-section should be designed to provide an adequate factor of safety to protect against sliding, sloughing, or rotation in the embankment or foundation. SCS's TR-60 publication provides guidelines for slope stability analysis when required. The most important factors in determining the stability of an embankment are:

1. **Physical characteristics of the fill materials**. Soil classification for engineering uses can be found in the SCS Engineering Field Manual, Chapter 4, and other references listed at the end of this section.

2. **Configuration of the site**. The height of the embankment may vary considerably throughout its length, so the total settlement of any given section of the embankment may differ from that of adjacent sections. The length of the embankment and slope of the abutments profoundly influence the degree of differential settlement between adjacent sections of the embankment. As the length shortens and the abutments become more steep, differential settlement becomes more likely. (**Minimum Standard 3.02**, **Principal Spillway** discusses the use of a concrete cradle to protect the spillway barrel sections from separating due to the forces of differential settlement.)

3. **Foundation materials**. The character and distribution of the foundation material must be considered for its *shear strength*, *compressibility*, and *permeability*. Occasionally, the shear strength of the foundation may govern the choice of embankment slopes. Permeability and stratification of the foundation may dictate the need for a *zoned embankment*. Quite often, foundations contain compressible soils that settle under the weight of the embankment, although the shear strength of these soils is satisfactory. When such settlement occurs in the foundation, the embankment settles. This settlement is rarely uniform over the basal area of the embankment. Therefore, fill materials used on such sites must be sufficiently plastic to deform without cracking. (**Minimum Standard 3.02**, **Principal Spillway** discusses the use of a concrete cradle to protect the spillway barrel sections from separating due to the forces of differential settlement.)

A foundation composed of homogeneous soil is simple to evaluate; however, this condition rarely occurs in natural soil deposits. Most often, a stratified deposit composed of layers of several soil types is encountered. To determine the suitability of such a foundation, the following information becomes very important: 1) *the geologic history of the site*, 2) *the degree of stratification*, and 3) *the order in which materials occur within the stratification*. A complex, stratified foundation containing plastic or compressible soil should be investigated by an experienced engineer or geologist.

**Foundation cutoff** - A foundation cutoff trench of moderately impervious material should be provided under the embankment. The cutoff trench should be installed at or upstream of the dam's centerline, and should extend up the abutments to the 10-year water surface elevation.

The bottom of the cutoff trench should be wide enough to accommodate excavation, backfill and compaction equipment. The trench's minimum width and depth should be 4 feet and the side slopes should be no steeper than 1H:1V (refer to **Figures 3.01-1a,b** and **3.01-2**).

**Rock foundations** - The presence of rock in the embankment foundation area requires specific design and construction recommendations (provided in the geotechnical engineering analysis) to insure a proper bond between the foundation and the embankment.

Generally, no blasting should be permitted within 100 feet of the foundation and abutment area. If blasting is essential, it should be carried out under controlled conditions to reduce adverse effects on the rock foundation, such as over-blasting and opening fractures. This is especially critical in areas of Karst topography.

**Embankment zoning and seepage** - The stability of an embankment slope and the seepage pattern through it are greatly influenced by the *zoning of the embankment*. (Refer to **Embankment Types** in the **Planning Considerations** section of this standard.) The position of the saturation line within a homogeneous embankment is theoretically independent of the type of soil used in it. Although soils vary greatly in regard to permeability, even the tightest clays are porous and cannot prevent water from seeping through them. **The rate of seepage through an embankment is dependent on the consistency of the reservoir level and the permeability of the embankment or core material**.

The upper surface of seepage is called the *phreatic surface* (zero pressure). In a cross-section, it is called the *phreatic line*. The position of the phreatic line in a retention basin embankment can be assumed to begin at the normal pool elevation on the upstream slope and extend at a 4H:1V slope downward through the embankment. **This assumption is based on the presence of a permanent pool**. For detention and extended-detention facilities with no permanent pool, many designers assume that the embankment will not impound water long enough for a phreatic surface to occur. This assumption, however, is based on a properly designed, constructed, and maintained embankment. Many jurisdictions, therefore, have chosen a conservative design approach by requiring that the phreatic line start at the 10-year design storm water surface elevation, regardless of the presence of a permanent pool.

For most stormwater management facilities, determining the location of the phreatic surface will often suggest the need to install seepage collars on the barrel. (Refer to **Minimum Standard 3.02, Principal Spillway**, for a discussion on seepage control along conduits.) For larger stormwater facilities, especially those with a permanent pool, the location of the phreatic surface may require additional design considerations such as an internal drain.

If the saturation line intersects the downstream slope of the embankment at a point above the toe, then seepage will exit the embankment along the downstream face and toe. Typically, the quantity of seepage is so slight that it does not affect the slope's stability. However, sometimes the saturation of the toe will cause sloughing or serious reduction of the shear strength in the downstream section of the embankment. Seepage control should be included in the design if the following conditions exist:

- pervious layers in the foundation are not intercepted by the cutoff,
- possible seepage from the abutments may create a wet embankment,
- the phreatic line intersects the downstream slope, or
- special conditions exist which require drainage to insure a stable embankment.

For *seepage collar design*, it is recommended that the phreatic line start at the 10-year design storm water surface elevation and extend through the embankment at a 4H:1V slope. **If the phreatic line intersects the downstream slope, a qualified soil scientist should be consulted to decide if additional controls are needed**. The location of the phreatic surface, therefore, may have a significant impact on the design of the embankment.

Seepage may be controlled by:

- foundation, abutment or embankment drains,

- a downstream drainage blanket,
- a downstream toe drain, or
- a combination of these measures (see **Figure 3.01-1b**).

Seepage encountered in the cutoff trench during construction may be controlled by *foundation drains*. These drains must be downstream of the embankment centerline and outside the limits of the proposed cutoff trench.

Including a toe drain in the design of most homogeneous embankments may be desirable. Embankments built on pervious foundations or constructed of materials that exhibit susceptibility to piping and cracking should always be protected by adequate toe drainage. Toe drains may be constructed of sand, gravel, or rock, depending on the nature of the embankment fill material. Whenever a rock toe drain is installed, a graded filter should be placed between the fill and the drain. Often, a 12-inch layer of well-graded, stream-run, sandy gravel will satisfy this requirement. Filter and drainage diaphragm design criteria are presented in the references listed as USDA-SCS Soil Mechanics Notes No. 1 and No. 3 at the end of this section, and provided in **Chapter 5 Appendix 5B**.

Piping

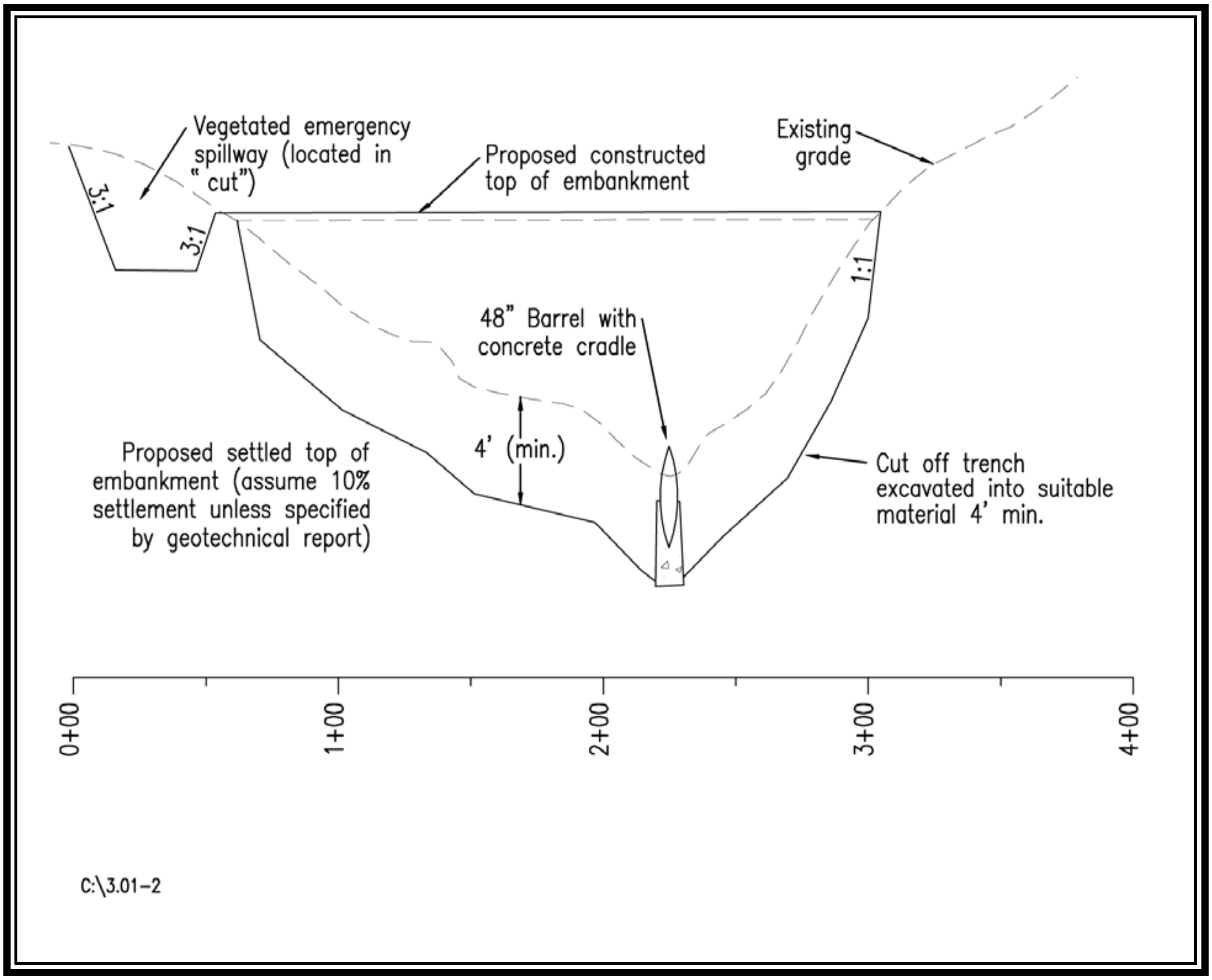
The contact areas between the embankment soils, foundation material, abutments, and conduits are the most susceptible locations for *piping failures.* Piping occurs due to the variation in materials at contact points and the difficulty in compacting the soil in these areas. Compaction is especially difficult next to and under conduits and seepage collars. Therefore, it is highly recommended that all utility conduits, except the principal spillway, be installed away from the embankment. When utility conduits through the embankment cannot be avoided, they should meet the requirements for spillways, i.e., water tight joints, no gravel bedding, restrained to prevent joint separation due to settlement, etc.

Seepage along pipe conduits that extend through an embankment should be controlled by use of the following:

- anti-seep collars, or
- filter and drainage diaphragms.

Refer to **Minimum Standard 3.02, Principal Spillway** for additional information on the use of anti-seep collars. Filter and drainage diaphragms are presented in USDA-SCS Soil Mechanics Notes No. 1 and No. 3, available upon request from DCR or USDA-SCS. When filter and drainage diaphragms are used, their design and construction should be supervised by a registered professional engineer.

**FIGURE 3.01 - 2**
***Profile Along Centerline of Embankment***




<u>Embankment Geometry</u>

1. **Height** - The height of an earthen embankment is based upon the freeboard requirements relative to the maximum water surface elevation during the 100-year frequency storm event. **An embankment <u>with</u> an emergency spillway must provide at least 1 foot of freeboard from the maximum 100-year storm water surface elevation (WSE) to the lowest point on the top of the embankment (excluding the emergency spillway)**. (Note that the *spillway design storm W.S.E*, if specified, may be used instead of the 100-year elevation.)

**An embankment without an emergency spillway must provide at least 2 feet of freeboard from the maximum 100-year storm WSE to the lowest point on the top of the embankment**. (Note that the *spillway design storm WSE*, if specified, may be used instead of the 100-year elevation.)

2. ***Top Width*** - The top of an earthen embankment should be shaped to provide positive drainage. The top width is based on the following table:

**TABLE 3.01 - 1**
***Embankment Top Widths***

| Total Height of Embankment (*ft.*) | Minimum Top Width (*ft.*) |
|---|---|
| 14 or less | 8 |
| 15-19 | 10 |
| 20-24 | 12 |
| 25 or more | 15 |

Compacted Fill

The soil types, as covered in the geotechnical analysis, should be specified by using the Unified Soil Classification System.

The compaction requirements should include the percent of maximum dry density for the specified density standard, allowable range of moisture content, and maximum loose lift thickness. Refer to **Construction Specifications for Earthen Embankments** later in this standard. In general, the design of an embankment should account for approximately 10% settlement unless otherwise specified by a geotechnical report based on the embankment foundation and fill material. The top of the embankment must be level in order to avoid possible overtopping in one location in cases of extreme storms or spillway failure.

Compaction tests should be performed regularly throughout the embankment construction; typically, one test per 5,000 square feet on each layer of fill or as directed by the geotechnical engineer. Generally, one of two compaction tests will be specified for embankment construction: the *Standard Proctor Test* (ASTM D698) or the *Modified Proctor Test* (ASTM D1557). For the construction of earth dams, the Modified Proctor Test is likely to be more appropriate (Terzaghi, Peck, 1948).This is due in part to the unconfined nature of the earth fill for dam construction. A new Proctor test is required if the material changes from that previously tested.

Embankment Construction

A geotechnical or construction inspector should be on site during embankment construction. Inspectors should be required to do more than just test fill compaction, i.e., observe foundation preparation, pipe installation, riser construction, filter installation, etc. (Refer to inspection checklist for impoundment structures, **Appendix 3**).

*A vertical trench through the embankment material to place the spillway pipe should not be allowed under any circumstances. Trench side slopes should be laid back in steps at a 2:1 slope, minimum.*

Maintenance and Safety

Embankment slopes should be no steeper than 3H:1V if possible, with a maximum combined upstream and downstream slope of 5:1 (3:1 downstream face and 2:1 upstream face). For embankments exceeding 15 feet in height, a 6 to 10 foot wide bench should be provided at intervals of 10 to 15 feet of height, particularly if slopes are steeper than 3H:1V.

The following design considerations are provided to help reduce the long-term maintenance burden on the owner(s):

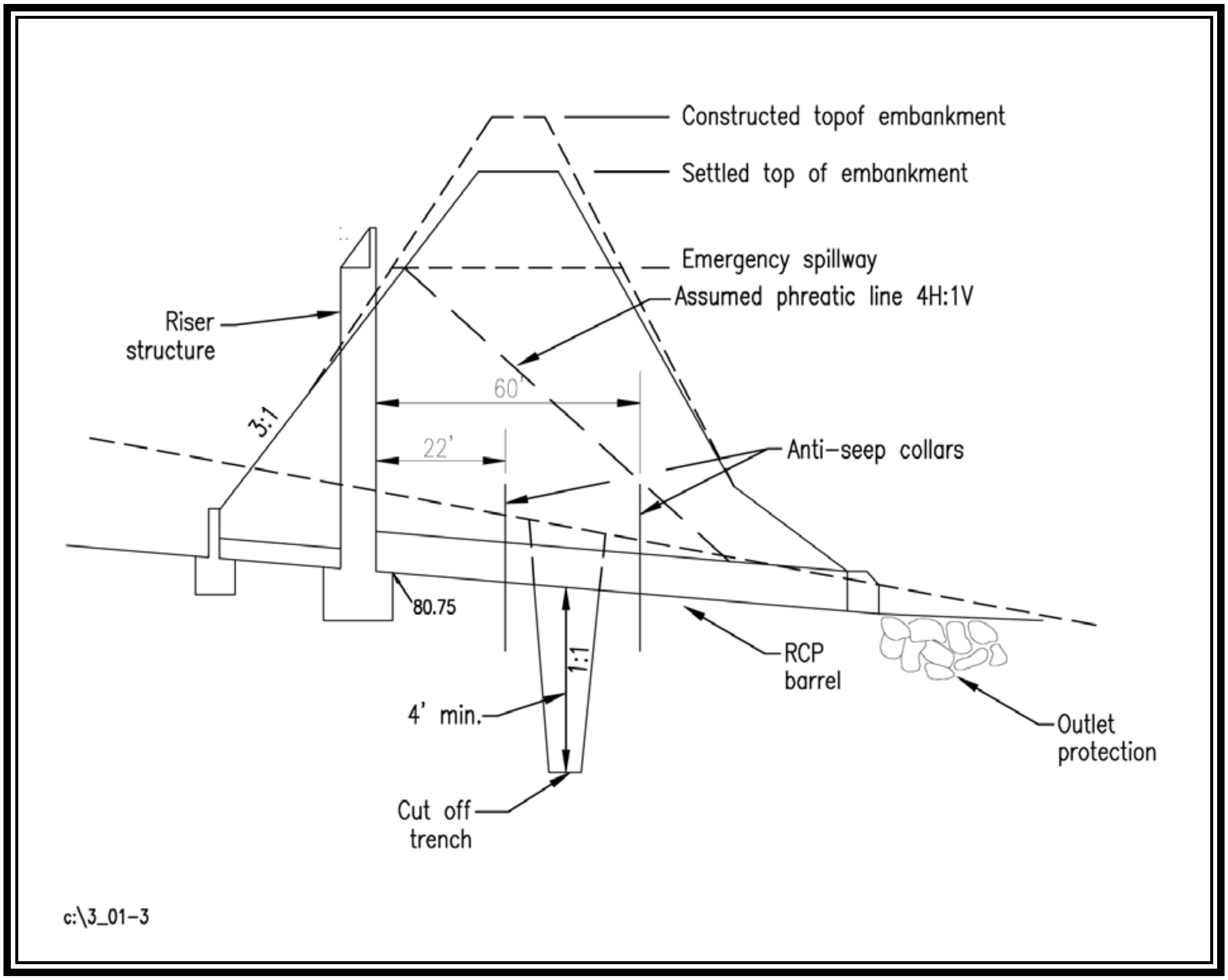
1. *Internal drainage systems in embankments (e.g., drainage blankets, toe drains)* should be designed such that the collection conduits discharge downstream of the embankment at a location where access for observation is possible by maintenance personnel.

2. *Adequate erosion protection* is recommended along the contact point between the face of the embankment and the abutments. Runoff from rainfall concentrates in these areas and may reach erosive velocities depending on the gutter slope and embankment height. Although a sod gutter will be satisfactory for most small embankments, an evaluation should be made to decide if another type of gutter protection is required. For most embankments, a riprap gutter is preferred to a paved concrete gutter.

3. *Trees, shrubs, or any other woody plants should not be planted on the embankment* or adjacent areas extending at least 25 feet beyond the embankment toe and abutment contacts.

4. *Access should be provided to all areas of an impoundment that require observation or regular maintenance*. These areas include the embankment, emergency spillway, basin shoreline, principal spillway outlet, stilling basin, toe drains, riser structure, extended-drawdown device, and likely sediment accumulation areas.

**FIGURE 3.01 - 3**
***Profile Along Centerline of Principal Spillway***



## Construction Specifications

The construction specifications for earthen embankments outlined below should be considered as minimum guidelines, with the understanding that more stringent specifications may be required depending upon individual site conditions, as evaluated by the geotechnical engineer. Final construction specifications should be included on the construction plans. In general, widely accepted construction standards and specifications for embankments, such as those developed by the USDA Soil Conservation Service or the U. S. Army Corps of Engineers, should be followed.

Further guidance can be found in the SCS Engineering Field Manual and National Engineering Handbook. Specifications for the embankment work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government.

### Site Preparation

Areas designated for borrow sites, embankment construction, and structural work should be cleared, grubbed and stripped of topsoil. All trees, vegetation, roots and other objectional material should be removed.

All cleared and grubbed material should be disposed of outside and below the limits of the embankment and reservoir, as directed by the owner or his representative. When specified, a sufficient quantity of topsoil should be stockpiled in a suitable location for use on the embankment and other designated areas.

### Earth Fill

1. **Material** - Fill material should be taken from an approved, designated borrow area. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, and frozen or other objectionable materials. Fill material for the center of the embankment and the cutoff trench should conform to Unified Soil Classification GC, SC, or CL. Consideration may be given to the use of other materials in the embankment if the design and construction are supervised by a geotechnical engineer.

2. **Placement** - Areas on which fill is to be placed should be scarified before its placement. Fill material should be placed in layers a maximum of 8 inches thick (before compaction), which should be continuous over the entire length of the fill. The most permeable borrow material should be placed in the downstream portions of the embankment. The principal spillway must be installed concurrently with fill placement and **not excavated** into the embankment.

3. **Compaction** - Fill material should be compacted with appropriate compaction equipment such as a sheepsfoot, rubber-tired or vibratory roller. The number of required passes by the compaction equipment over the fill material may vary with soil conditions. Fill material should contain sufficient moisture such that the required degree of compaction will be obtained with the equipment used.

   The minimum required density is 95% of maximum dry density with a moisture content within ± 2% of the optimum, unless otherwise specified by the engineer. Each layer of the fill should be compacted as necessary to obtain minimum density and the engineer should certify, at the time of construction, that each fill layer meets the minimum density requirement. All compaction is to be determined by either Standard Proctor Test (ASTM D698) or the Modified Proctor Test (ASTM D1557) as directed by the geotechnical enginer based on site and soil conditions and the size and type of structure being built.

4. **Cutoff Trench** - The cutoff trench should be excavated into impervious material along or parallel to the centerline of the embankment as shown on the plans. The bottom width of the trench should be governed by the equipment used for excavation, with the minimum width being 4 feet. The depth should be at least 4 feet below existing grade or as shown on the plans. The side slopes of the trench should be 1H:1V or flatter. The backfill should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability.

5. **Top Soil** - The surface layer of compacted fill should be scarified prior to placement of at least 6 inches of top soil. The top soil shall be stabilized with in accordance with the Virginia Erosion and Sediement Control Handbook, latest edition.

<u>Structure and Conduit Backfill</u>

Backfill that is beside pipes or structures should be of the same type and quality as specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should completely fill all spaces under and beside the pipe. During the backfilling operation, equipment should not be driven closer than 4 feet, as measured horizontally, to any part of a structure. Also, equipment should **NEVER** be driven over any part of a structure or pipe, unless compacted fill has been placed to a depth specified by the structural live load capacity of the structure or pipe in order to adequately distribute the load.

<u>Filters and Drainage Layers</u>

In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

Up to four feet of embankment material may be placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12 inch lifts of filter material, flooded, and vibrated as described above, until the top of adjacent fill is reached.

**Filter fabrics should not be used in lieu of sands and gravel layers within the embankment**.

## Maintenance and Inspection Guidelines

A thick, healthy grass cover, free of trees and brush, should be maintained on the embankment. Such a cover will help stabilize the surfaces of the embankment and will simplify inspections.

The maintenance and inspection guidelines presented below are **NOT** all-inclusive. Specific facilities may require other measures not discussed here. It is the designer's responsibility to decide if additional measures are necessary.

1. The embankment should be mowed periodically during the growing season, ensuring that the last cutting occurs at the end of the season. The grass should not be cut less than 6 to 8 inches in height.

2. If necessary, the embankment should be limed, fertilized and seeded in the fall, after the growing season. Lime and fertilizer application rates should be based on soil test results. The type of seed should be consistent with that originally specified on the construction plans.

3. All erosion gullies noted during the growing season should be backfilled with topsoil, reseeded and protected (mulched) until vegetation is established.

4. All bare areas and pathways on the embankment should be properly seeded and protected (mulched) or otherwise stabilized to eliminate the potential for erosion.

5. All animal burrows should be backfilled and compacted and burrowing animals should be removed from the area.

6. All trees, woody vegetation and other deep-rooted growth, including stumps and associated root systems, should be removed from the embankment and adjacent areas extending to at least 25 feet beyond the embankment toe and abutment contacts. The root systems should be extracted and the excavated volume replaced and compacted with material similar to the surrounding area. All seedlings should be removed at the first

opportunity. Similarly, any vine cover and brush should be removed from the embankment to allow for inspections.

7. Any repairs made to the princpal spillway (riser or barrel) should be reviewed by a professional engineer. Vertical trenching to expose the barrel should not be allowed under any circumstances. The trench side slopes should be stepped back at a 2:1 slope, minimum.

## REFERENCES


ASTM D-2487. Classification of Soils for Engineering Purposes.

ASTM D-2488. Description and Identification of Soils (visual-manual procedure).

Maryland Department of the Environment-Dam Safety Division. Dos and Don’ts for Pond Construction. May 1997.

Sowers, George F. Introductory Soil Mechanics and Foundations: Geotechnical Engineering.

Terzaghi and Peck. Soil Mechanics in Engineering Practice.

USDA Soil Conservation Service. Engineering Field Manual.

USDA Soil Conservation Service. National Engineering Handbooks.

**USDA Soil Conservation Service, Soil Mechanics Notes:**

SM Note No. 1, Guide for Determining the Gradation of Sand and Gravel Filters.
SM Note No. 2, Light Weight Piston Sampler for Soft Soils and Loose Sands.
SM Note No. 3, Soil Mechanics Considerations for Embankment Drains.
SM Note No. 4, Preparation and Shipment of Undisturbed Core Samples.
SM Note No. 5, Flow Net Construction and Use.
SM Note No. 6, Glossary, Symbols, Abbreviations, and Conservation Factors.
SM Note No. 7, The Mechanics of Seepage Analysis.
SM Note No. 8, Soil Mechanics Testing Standards.
SM Note No. 9, Permeability of Selected Clean Sands and Gravels.
SM Note No. 10, The Static Cone Penatrometer: The Equipment and Using the Data.

**USDA Soil Conservation Service, Technical Releases:**

TR 709. Dimensioning of Filter-Drainage Diaphragms for Conduits According to TR-60.
TR 026. The Use of Soils Containing More Than 5% Rock Larger Than the No.4 Sieve.
TR 027. Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankments.
TR 028. Clay Minerals.
TR 071. Rock Materials Field Classification Procedure.
TR 60. Earth Dams and Reservoirs

U.S. Department of the Interior. Design of Small Dams. 1987.

U.S. Department of the Interior, Bureau of Reclamation. Guidelines for Controlling Seepage Conduits through Embankments.

Virginia Department of Conservation and Recreation. Virginia Erosion and Sediment Control Handbook. Richmond, Virginia: 1992.

# Chapter 3.01

Typical Earthen Embankment

Stabiliazation of newly constructed Earthen Embankment

# Earthen Embankment

## *MINIMUM STANDARD 3.02*

# PRINCIPAL SPILLWAY

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.02

# PRINCIPAL SPILLWAY

### Definition

A principal spillway is the primary outlet device for a stormwater impoundment. It usually consists of either a *riser structure in combination with an outlet conduit*, which extends through the embankment, or *a weir control section* cut through the embankment.

### Purpose

The purpose of a principal spillway is to provide a primary outlet for storm flows, usually up to the 10- or 25-year frequency storm event. The principal spillway is designed and sized to regulate the allowable discharge from the impoundment facility.

### Conditions Where Practice Applies

A principal spillway is used on any impoundment BMP, including retention, extended-detention, and detention facilities. It may also be used with constructed wetlands and infiltration measures.

### Planning Considerations

A principal spillway typically consists of a *multistage riser structure* and an outlet conduit or a *weir* that allows flow to pass over a *control section* of the embankment. The shape and geometry of the weir as well as that of the riser structure can be manipulated to meet the needs of the specific facility. The use of a weir as the principal spillway eliminates the barrel projecting through the embankment. The barrel through the embankment and the associated piping and seepage control represent not only significant material and construction costs, but also the potential trouble spots for long term maintenance and possible repair.

The most common type of riser structure is a *drop inlet spillway*. A drop inlet spillway usually consists of a rectangular or other shaped riser structure containing one or several openings sized to control one or more discharge rates. For aesthetic or safety concerns, the drop inlet riser structure may be installed in the embankment with only its top showing. The discharge openings may be extended to the design water surface elevations with pipe. See **Figures 3-02.1(a-f)** for typical riser structures and locations.

The barrel shape or geometry and size through the embankment is based upon the required flow capacities and availability of materials.

## Design Criteria

The purpose of this section is to provide minimum design recommendations and guidelines for principal spillway systems (riser structure and barrel). The designer is responsible for determining those aspects that are applicable to the particular facility being designed, and for determining if any additional design elements are required to insure the long-term functioning of the system.

***The crest elevation of the principal spillway must be at least 1.0 ft. below the crest of the emergency spillway.***

Drop Inlet Spillways

Drop inlet spillways (riser and barrel system) should be designed such that a) *full flow is established in the outlet conduit and riser at the lowest head over the riser crest as is practical*, and b) *the facility operates without excessive surging, noise, vibration, or vortex action at any stage*. To meet these two requirements, the riser must have a larger cross-sectional area than the outlet conduit. **Chapter 5** provides the basic hydraulic calculation procedures needed to design the spillway riser and barrel system.

Headwall/Conduit Spillways

Headwall spillways consist of a pipe extending through an embankment with a headwall at the upstream end. The headwall is typically oversized to provide an adequate surface against which to compact the embankment fill.

Weir Spillways

A weir spillway, when used as a principal spillway, should be armored with concrete or other non-erosive material, since it usually carries water during every storm event. At the spillway, armoring should extend from the upstream face of the embankment to a point downstream of the spillway toe.

In general, all principal spillways should be constructed of a nonerosive material. The selected material should have an anticipated life expectancy similar to that of the stormwater management facility. Precast riser structures can not be substituted if plans call for a cast in place structure, unless approved by the design engineer and the plan approving authority. Sections of precast structures must be anchored together for stability and flotation requirements. A structural engineer should evaluate shop drawings for pipe, precast structures, or other fabricated appurtenances before fabrication or installation. **Cinder block and masonry block structures should not be used**.

Vegetated spillways designed to carry flow during the 100-year frequency storm or greater are discussed in **Minimum Standard 3.03**, **Vegetated Emergency Spillway**.

Combined Principal and Emergency Spillways

An *emergency spillway*, separated from the principal spillway, is generally recommended. However, using an overland emergency spillway at the embankment abutments may not be practical due to site limitations, such as the following:

- topographic conditions (e.g., abutments are too steep)
- land use conditions (e.g., existing or proposed development imposes constraints)
- other factors (e.g., roadway embankments are used as a dam, basins are excavated, etc.).

In these instances, a *combined principal/emergency spillway* may be considered. A combined principal/emergency spillway is simply a single spillway structure that conveys both low flows and extreme flows (such as the 100-year frequency flow). The combined spillway may take the form of a drop inlet spillway, a weir spillway, a headwall/conduit spillway or any other spillway type.

***A primary design consideration for a combined principal/emergency spillway, particularly if it is a drop inlet spillway, is protection against clogging.***

**FIGURE 3.02 - 1a**
*Typical Principal Spillway Structures*

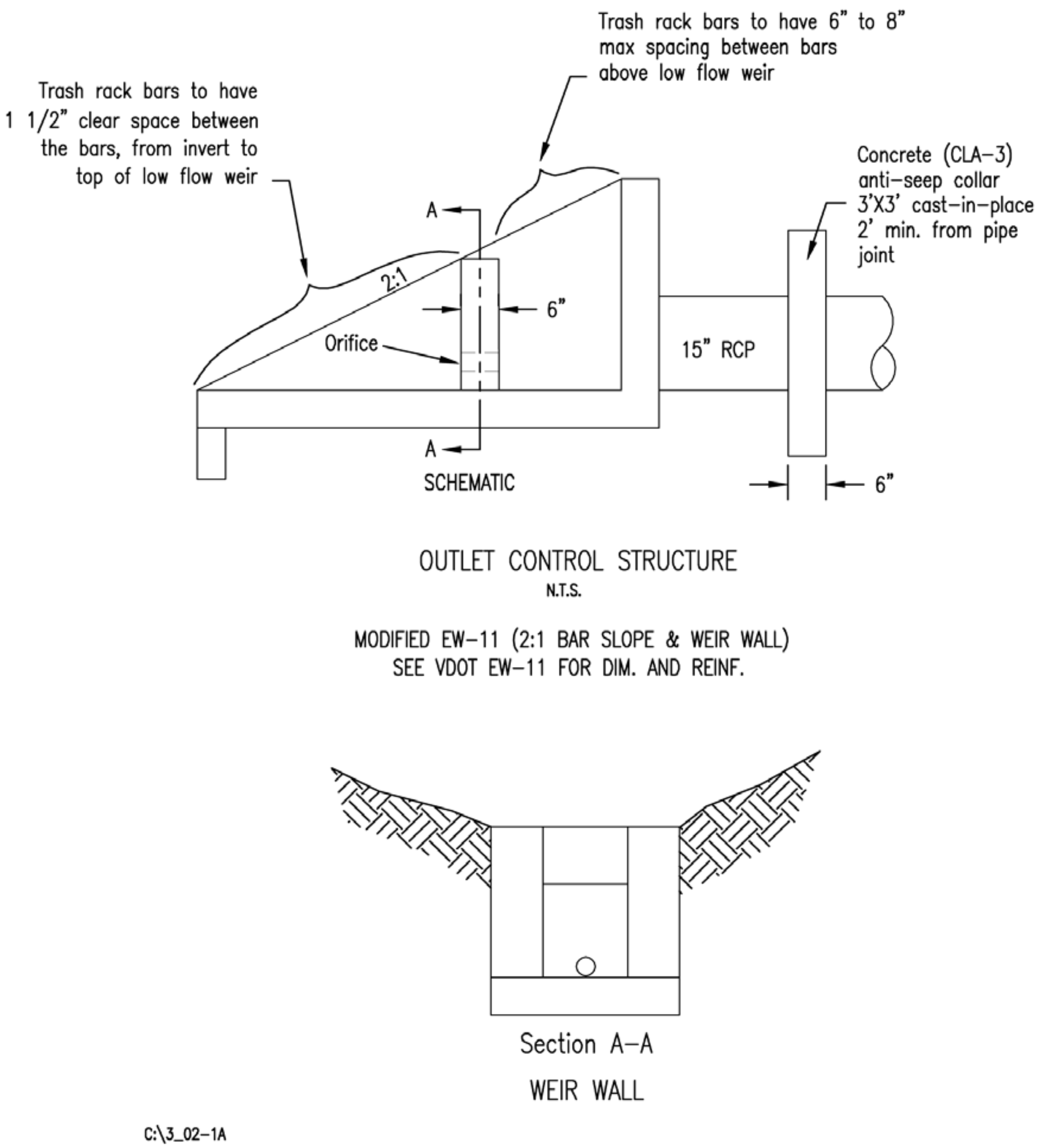


**FIGURE 3.02 - 1b**
***Typical Principal Spillway Structures***

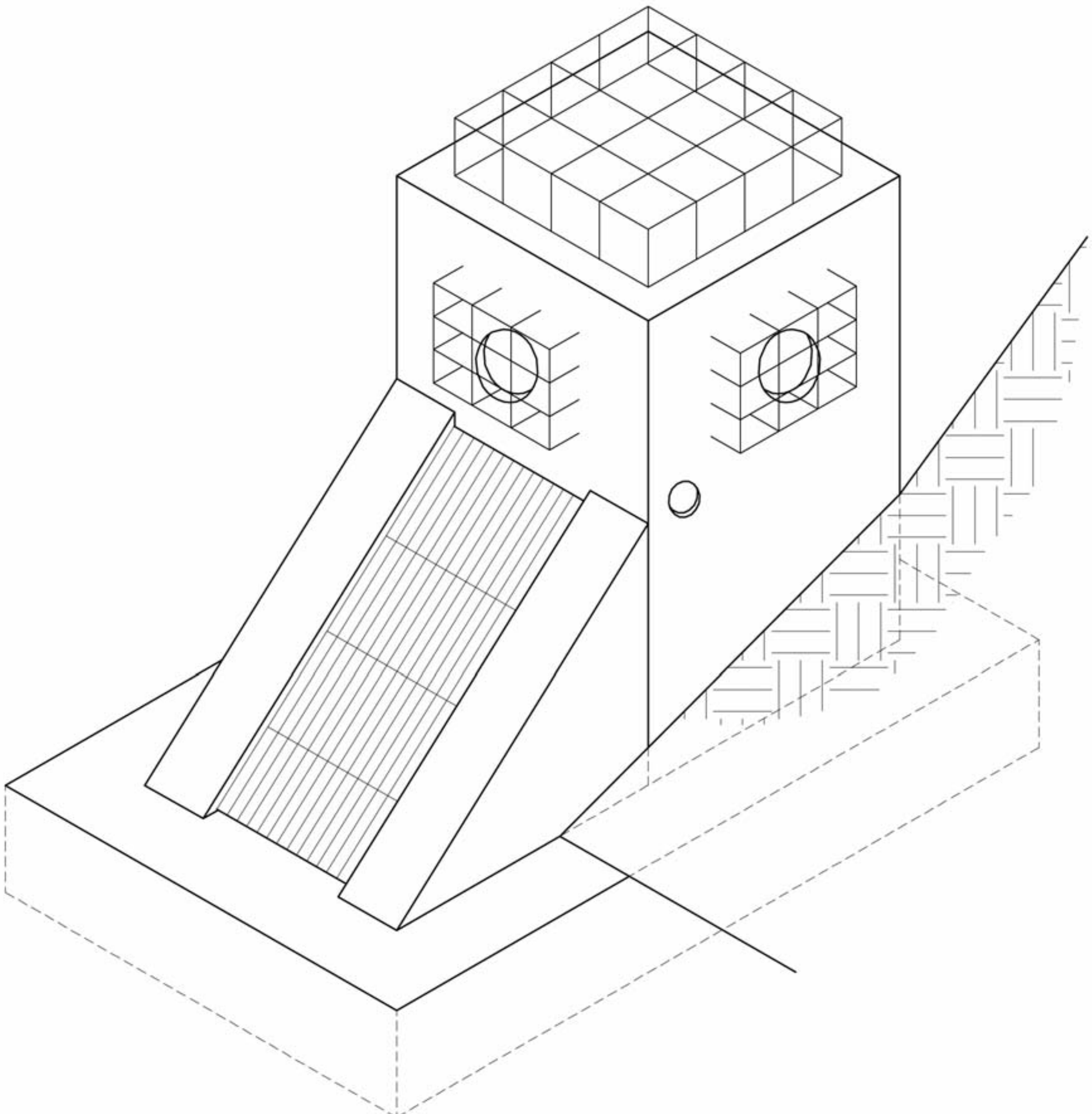


**FIGURE 3.02 - 1c**
*Typical Principal Spillway Structures*

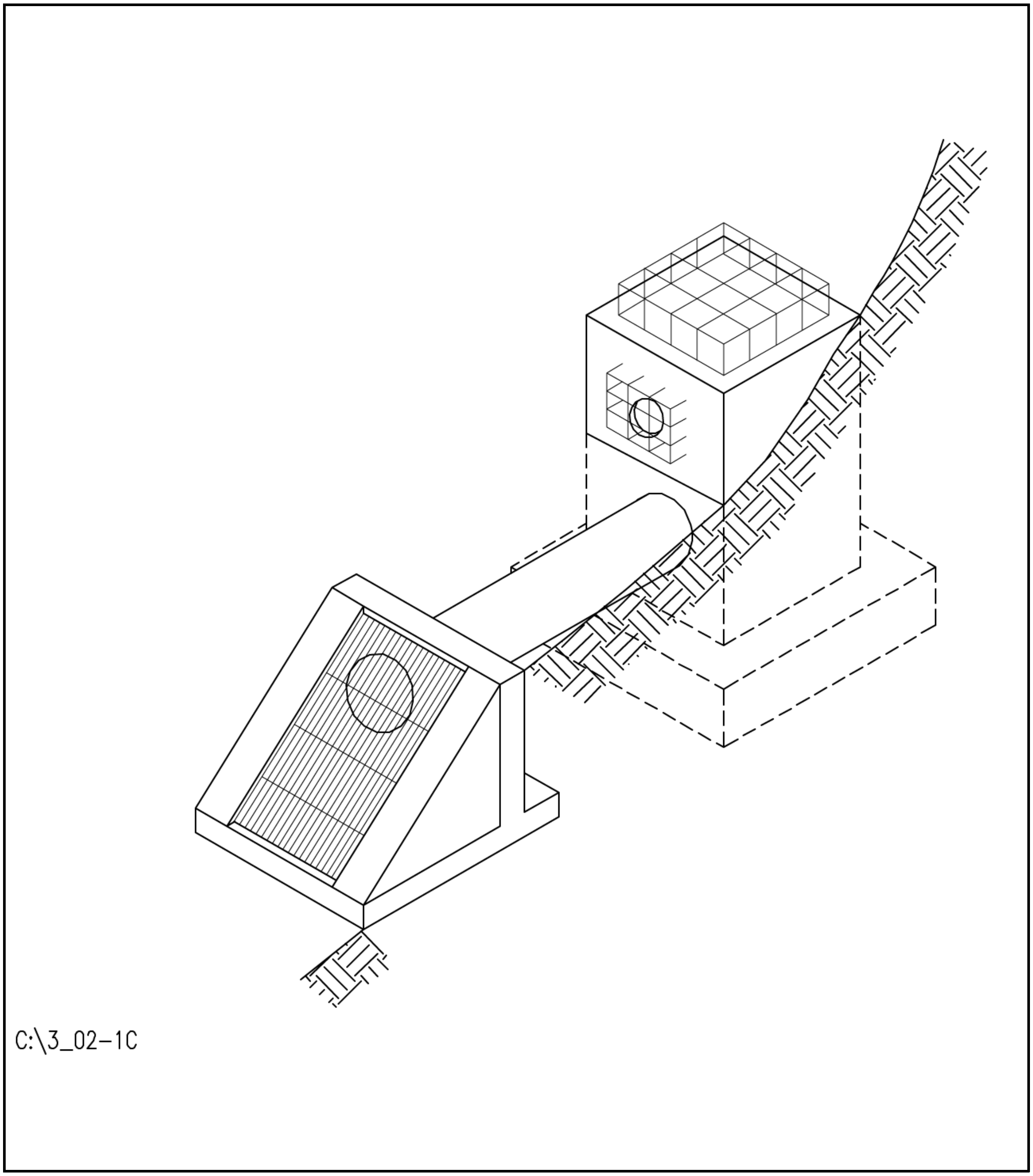


**FIGURE 3.02 - 1d**

***Typical Principal Spillway Structures***

**FIGURE 3.02 - 1e**
*Typical Principal Spillway Structures*

**FIGURE 3.02 - 1f**
***Typical Principal Spillway Structures***

**FIGURE 3.02 - 1g**
*Typical Principal Spillway Structures*

Conduits/Structures through Embankments

The *contact point* between the embankment soil, the foundation material, and the conduit is the most likely location for *piping* to occur due to the discontinuity in materials and the difficulty in compacting the soil around the pipe. Therefore, special attention must be given to the design of any conduit that penetrates an embankment.

***It is highly recommended that the designer limit the number of conduits that penetrate through an embankment. Whenever possible, utility or other secondary conduits should be located outside of and away from the embankment. When additional conduits cannot be avoided, they should meet the requirements for spillways i.e., water tight joints, no gravel bedding, encasement in concrete or flowable fill, restrained to prevent joint separation due to settlement, etc.***

Many embankment failures occur along the principal spillway because of the difficulty in compacting soil along a pipe. To help alleviate this concern, designers should consider the use of a weir as an control structure.

An additional cause of embankment failure is the separation of pipe joints due to differential settlement and pipe deflection. Corrugated metal pipe (CMP) must meet or exceed the minimum required thickness specified in **Table 3.02-1**. The contractor and project inspector should verify the metal thickness (compare manufacturer's certification which accompanies the pipe shipment with the plan specifications), corrugation size, proper connecting bands, and gasket type. Maximum allowable deflection of CMP conduits is 5% of the pipe diameter. However, with larger pipe sizes, it may be difficult to get water tight joints even if the deflection is less than that which is allowed. For increased design life, the engineer may choose to specify a heavier gage than indicated in **Table 3.02-1**.

Water tight joints are necessary to prevent infiltration of embankment soils into the conduit. All joints must be constructed as specified by the pipe manufacturer. "Field joints" where the ends of the pipes are cut off in the field should not be accepted. In addition, six inch hugger bands and "dimple bands" should not be accepted for CMP conduits. The construction specifications (found later in this Standard) specify 12-inch bands with 12-inch O-ring or flat neoprene gaskets for pipes 24 inches or less in diameter. Larger pipes require 24-inch wide bands with 24-inch wide flat gaskets and four "rod and lug" type connectors. Flanged pipe with gaskets is also permitted. Refer to the Construction Specifications in this standard for more information.

All pipe gaskets should be propely lubricated with the material provided by the pipe manufacturer.

Use of an incorrect lubricant may cause deterioration of gasket material.

**Conduit Piping and Seepage Control** – *Seepage* or *piping* along a pipe conduit, which extends through an embankment, should be controlled by use of one of the following: 1) *anti-seep collars*, as shown in **Figure 3.02-2**, or 2) *filter or drainage diaphragms* as shown in **Figure 3.02-3**. Concrete cradles, as discussed in item 3 below, may also be used.

***Seepage control will not be required on pipes less than 6 inches in diameter.***

1. *Anti-Seep Collars* - These collars lengthen the percolation path along the conduit, subsequently reducing the *exit gradient*, which helps to reduce the potential for piping. While this works well in theory, the required quality of compaction around the collars is very difficult to achieve in the field.

The Bureau of Reclamation, the U.S. Army Corps of Engineers, and the Soil Conservation Service no longer recommend the use of anti-seep collars. The Bureau of Reclamation issued Technical Memorandum No. 9 in 1987 that states:

> *"When a conduit is selected for a waterway through an earth or rockfill embankment, cutoff collars will not be selected as the seepage control measure."*

Alternative measures have been developed and used in the designs of major structures. These measures include *graded filters* or *filter diaphragms*, and *drainage blankets*. These devices are not only less complicated and more cost-effective to construct than the cutoff collars, but also allow for easier placement of the embankment fill.

Designers and engineers, however, continue to use anti-seep collars as the sole method of seepage control for small dams. This may be due to the complexity of the design procedure for graded filters. It may also be due to the designer's concern that little engineering supervision and/or inspection will occur during construction, which is generally necessary for the successful installation of graded filters.

Anti-seep collars, when used, should be installed around all conduits through earth fills according to the following criteria:

a. Enough collars should be placed to increase the seepage length along the conduit by a minimum of 15%. This percentage is based on the length of pipe in the saturation zone.

b. The assumed normal saturation zone should be determined by projecting a line through the embankment, with a 4H:1V slope, from the point where the normal water elevation meets the upstream slope to a point where it intersects the invert of the conduit. This line, referred to as the *phreatic line*, represents the upper surface of the zone of saturation within the embankment. For stormwater management basins, the phreatic line starting elevation should be the 10-year storm pool elevation. (See **Minimum Standard 3.01**, **Earthen Embankment**.)

c. Maximum collar spacing should be 14 times the minimum projection above the pipe. The minimum collar spacing should be 5 times the minimum projection.

d. Anti-seep collars should be placed within the saturation zone. In cases where the spacing limit will not allow this, at least one collar should be in the saturation zone.

e. All anti-seep collars and their connections to the conduit should be watertight and made of material compatible with the conduit.

f. Collar dimensions should extend a minimum of 2 feet in all directions around the pipe.

g. Anti-seep collars should be placed a minimum of 2 feet from pipe joints unless flanged joints are used.

***The calculation procedure for sizing anti-seep collars is presented in Chapter 5: Multi-Stage Riser Design, STEP 15.***

**FIGURE 3.02 - 2**
*Anti-Seep Collar*

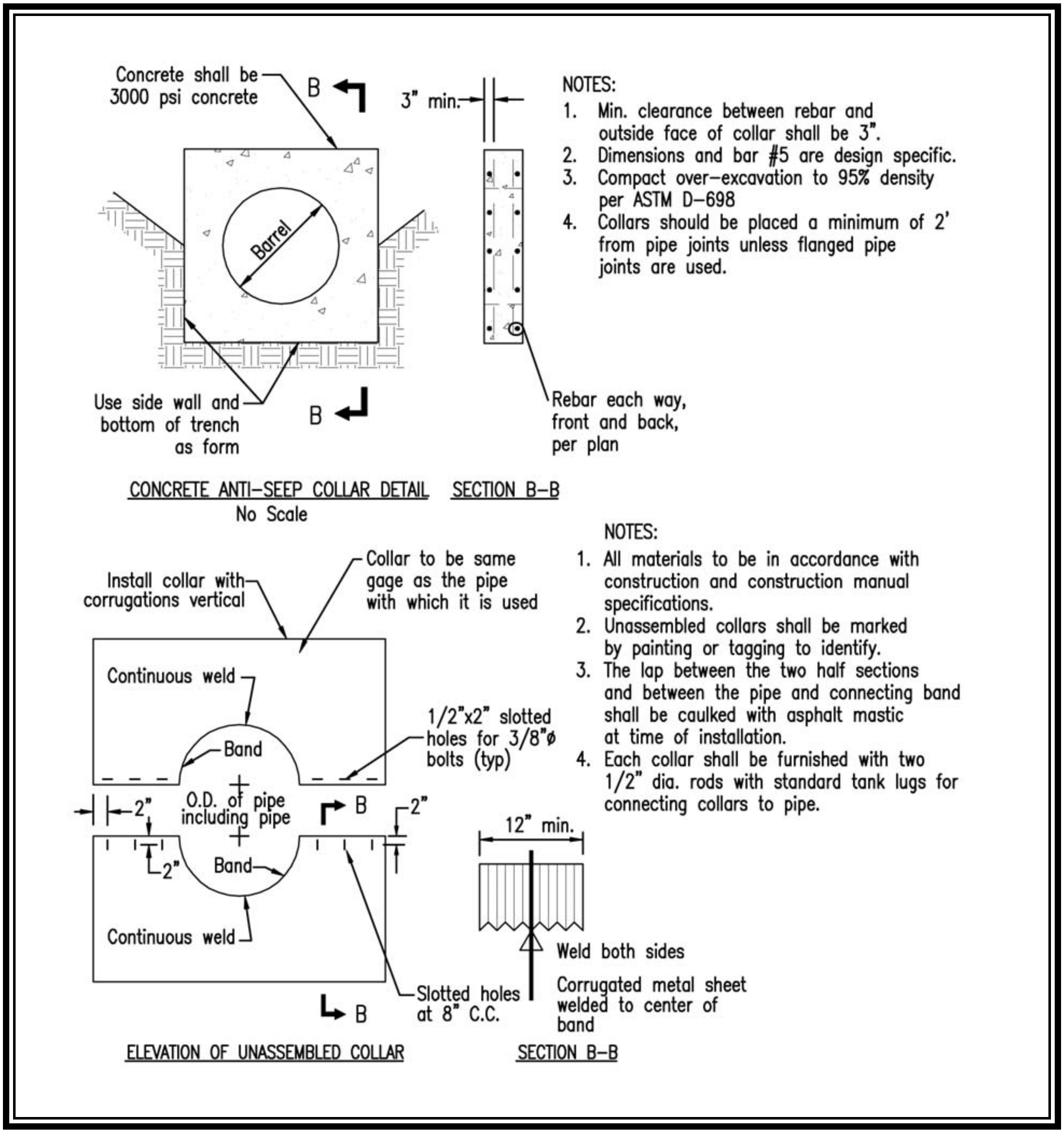
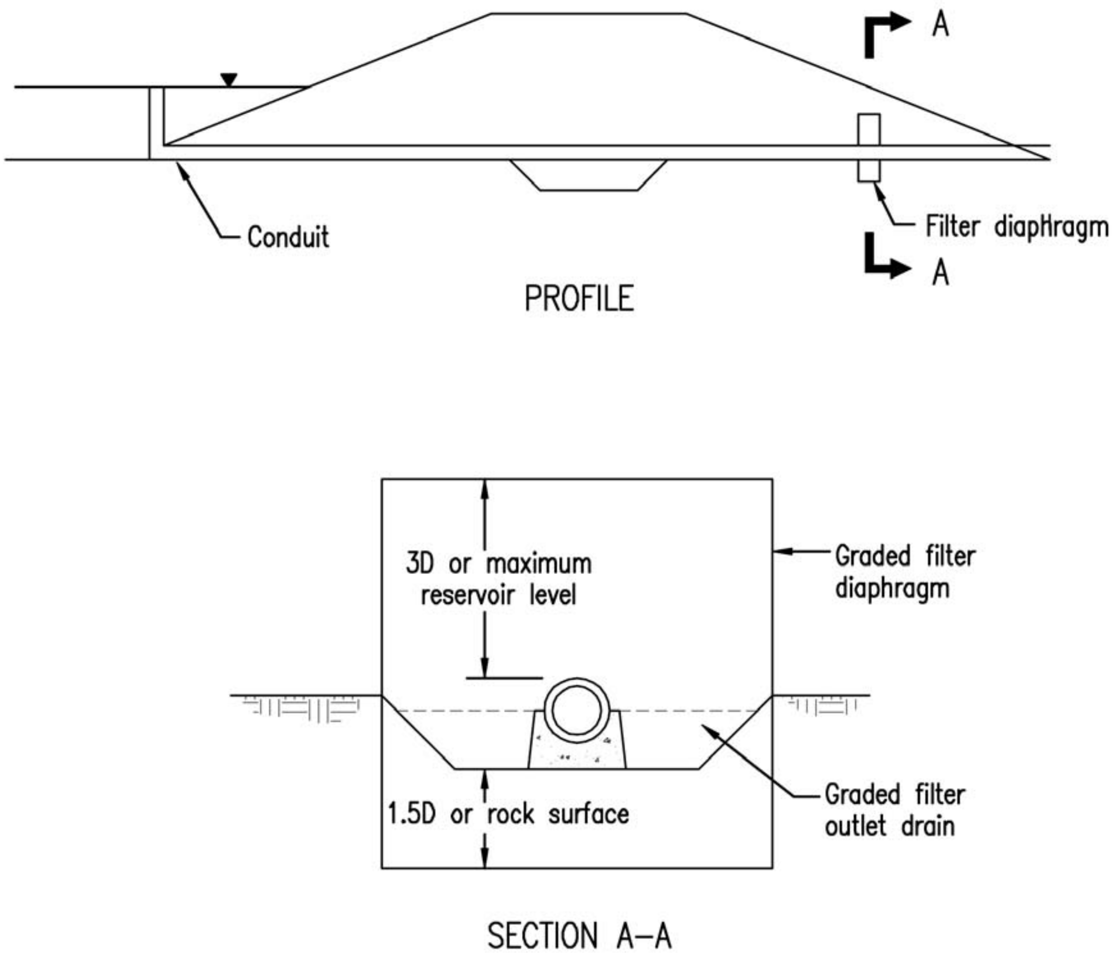


**FIGURE 3.02 - 3**
***Graded Filter Diaphragm for Seepage Control Around Conduit***




NOTES:
1. Delete filter diaphragm when conduit passes through chimney drain.
2. Delete outlet drain when filter diaphragm is connected to foundation drainage blanket.

c:\3_02–3

*Source: Seepage Control Along Conduits Penetrating Embankment Dams, Ray E. Martin, Ph.D., P.E.*

2. *Filter and Drainage Diaphragms* - Anti-seep collars extend the flow path along the conduit and, therefore, discourage piping. In contrast, filter and drainage diaphragms do not eliminate or discourage piping, rather they control the transport of embankment fines, which is the major concern in piping and seepage. Rather than trying to prevent seepage or increase its flow length, these devices channel the flow through a filter of fine graded material, such as sand, which traps any embankment material being transported. The flow is then conveyed out of the embankment through a perforated toe drain or other acceptable technique.

While filter and drainage diaphragms require careful design, the procedure is straightforward. The *grain size distribution* of the embankment fill and foundation material must be determined so that the filter material grain size distribution can be specified. If the specified filter material is not available on the site, it must be imported. The design procedure for filter and drainage diaphragms can be found in the following references:

Ë SCS TR-60
Ë SCS Technical Note No. 709
Ë SCS Soil Mechanics Notes 1 and 3 (Available upon request from DCR or NRCS)

There are some distinct advantages to using filter diaphragms over anti-seep collars:

¢ By eliminating the obstructions created by anti-seep collars, heavy compaction equipment can more thoroughly compact the embankment fill material adjacent to the conduit.

¢ The labor intensive formwork associated with anti-seep collar construction is eliminated.

¢ Cracks that form in the fill along the conduit will be terminated by the filter and will not propogate completely through the dam.

The design of filter and drainage diaphragms should be supervised by a geotechnical engineer. The critical design element is the grain size distribution of the filter material compared with that of the embankment fill and foundation material.

Overall, the following criteria apply to the use of filter and drainage diaphragms:

a. The diaphragm should consist of sand, meeting fine concrete aggregate requirements (at least 15% passing the No. 40 sieve but no more than 10% passing the No. 100 sieve). If unusual soil conditions exist, a special analysis should be completed.

b. The diaphragm should be a minimum of 3 feet thick and should extend vertically **upward** and **horizontally** at least 3 times the pipe diameter and vertically **downward** at least 24 inches beneath the barrel invert, or to rock, whichever is encountered first (SCS Tech. Note 709).

c. The diaphragm should be placed immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.

d. In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

   Up to four feet of embankment material may be placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12-inch lifts of filter material, flooded and vibrated as described above, until the top of adjacent fill is reached.

e. The diaphragm should be discharged at the downstream toe of the embankment. The opening sizes for slotted and perforated pipes in drains must be designed using the filter criteria. A second filter layer may be required around the drain pipe in order to alleviate the need for many very small openings. Fabric should <u>not</u> be used around the perforated pipe as it may clog rendering the perforations impenetrable by water.

The construction specifications for a filter diaphragm should include provisions to prevent settlement of the filter material upon saturation. This is usually accomplished by flooding the filter upon installation and compacting with vibratory equipment as soon as the water drops below the surface (Van Aller, 1990).

Whatever measures are taken to control seepage, proper construction techniques and inspection are critical to a successful project. The contractor should ensure that backfill material meets the specifications for *quality*, *lift thickness*, *placement*, *moisture content*, and *dry unit weight*. In addition, special care should be taken in the placement and compaction of the embankment material beside the barrel. Compaction along this conduit must extend away from the pipe enough to overlap with the compaction of the embankment. The use of filter and drainage diaphragms will ease this effort while providing greater protection against the damaging effects of piping and seepage.

***During construction, it is recommended that filter and drainage diaphragms be inspected by a qualified professional. Inspection logs should be submitted along with any as-built plans.***

3. *Concrete Pipe Bedding* - If the embankment fill material under the spring line of the conduit is **inadequately** compacted, *piping* may result. This problem is magnified if the conduit is not designed with flexible watertight joints; differential settlement of the embankment and foundation materials may pull the conduit joints apart, allowing the stormwater to escape into the surrounding soil, greatly adding to the piping condition. Installation of a concrete cradle will help to reduce the risk of piping under the barrel and the subsequent failure of the embankment, resulting from differential settlement.

Cradles not only provide conduit support, but also provide a better condition for the placement and compaction of backfill.

Concrete cradles serve two distinctly different, yet related functions: 1) *they help to prevent piping along the conduit,* and 2) *they provide a 90E* ***bedding angle*** *for the loading support of the conduit. See* ***Figure 3.02 - 4***.

The concrete cradle may not be necessary along the entire length of the conduit to prevent piping, but it is recommended. This will eliminate a sudden change in the support provided under the conduit. The load distribution of the conduit is assumed to be the same as the typical load distribution characteristics of reinforced concrete pipe (*RCP*). The external loading capacity of *RCP* depends upon a bedding condition that provides equal support around the base of the pipe. General pipe culvert installation specifications call for the placement of gravel under the pipe to distribute the load evenly. However, g**ravel bedding under an embankment conduit is <u>never</u> appropriate unless it is designed as a filter or drainage diaphragm.** Therefore, if the external load on the barrel is enough to warrant provision for its ***maximum supporting strength,*** then a concrete cradle should be installed along the conduit's entire length. Note that external loads on the barrel may be due to the height of the embankment fill, the anticipated construction traffic, or the weight of the compaction equipment.

**Single Conduits** – All conduits penetrating dam embankments should be designed using the following criteria:

a. Conduits and structures penetrating an embankment should have a smooth surface without protrusions or indentations that will hinder compaction of embankment materials.

b. All conduits should be circular in cross-section except cast-in-place reinforced concrete box culverts.

c. Conduits should be designed to withstand the external loading from the proposed embankment without yielding, buckling or cracking, all of which will result in joint seperation.

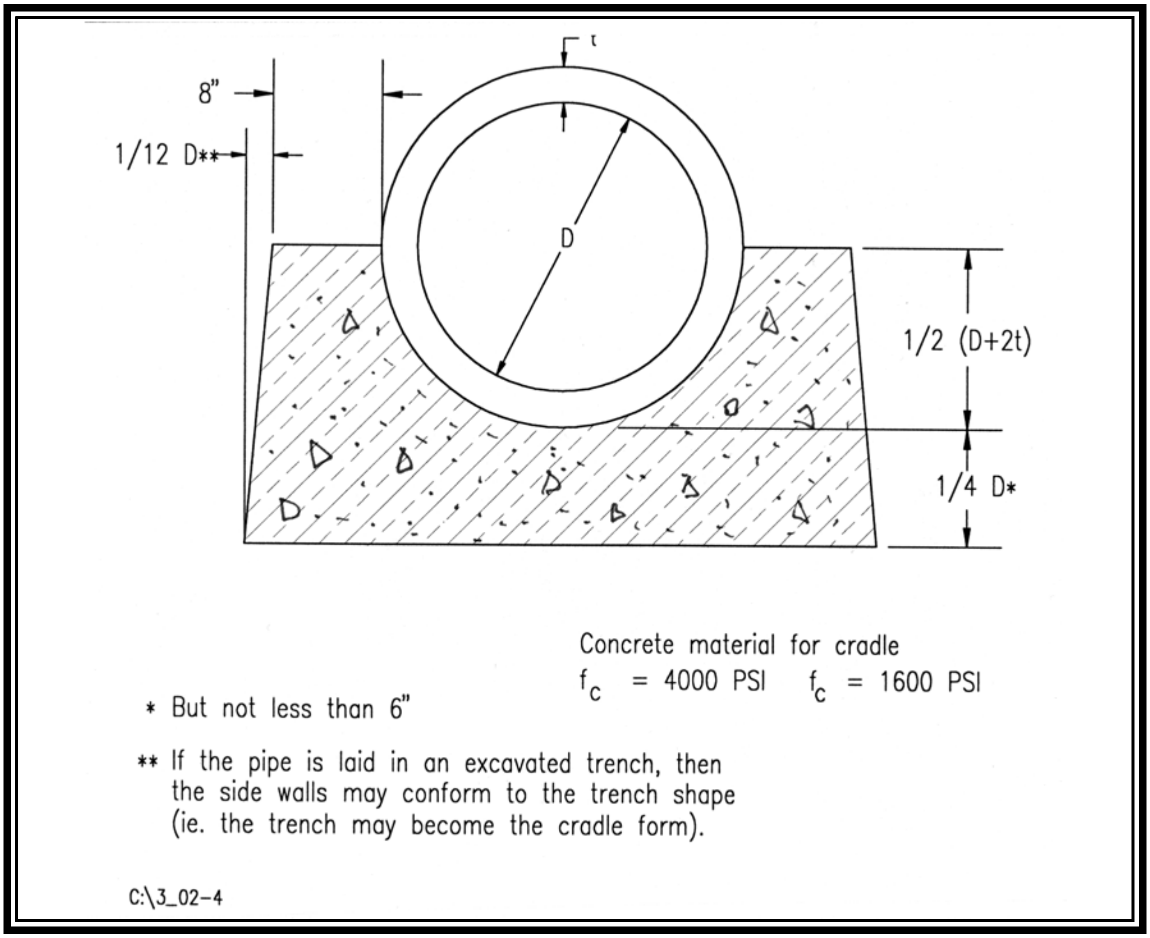
d. Conduit strength should not be less than the values shown in **Tables 3.02-1** and **3.02-2** for corrugated steel, aluminum, and PVC pipes, and the applicable ASTM standards for other materials. The manufacturer should submit certification that the pipe meets plan requirements for design load, pipe thickness, joint design, etc.

e. Inlet and outlet flared-end sections should be made from materials that are compatible with the pipe.

f. All pipe joints should be made watertight by using flanges with gaskets, coupling bands with gaskets, bell and spigot ends with gaskets, or by welding. See **Construction Specifications** later in this standard.

**Multiple Conduits –** Where multiple conduits are used, each conduit should conform to the requirements in item (b), above. In addition, sufficient space between the conduits and the installed anti-seep collars should be provided to allow for backfill material to be placed between the conduits with earth moving equipment and to allow for easy access by hand-operated compaction equipment. The distance between conduits should be equal to or greater than one-half of the pipe diameter, but not less than 2 feet.

**FIGURE 3.02 - 4**
***Concrete Cradle***




Cathodic Protection

In some areas of Virginia, sedimentary layers may be very acidic. This is particularly common in the coastal and piedmont regions east of the fall line, or roughly east of Interstate 95. Cathodic protection should be provided for *coated welded steel* and *galvanized corrugated metal* pipe when soil and resistivity studies indicate the need for a protective coating. Cathodic protection may also be provided when additional protection and longevity are warranted.

Outlet Protection

Outlet protection should be used on the downstream toe of a spillway structure to help dissipate the high energy flow through the spillway and to prevent excessive erosion in the receiving channel.

Various types of outlet protection can be used including: *riprap at the endwall or end-section of an outlet conduit* or a *designed hydraulic jump with impact blocks*. The type of outlet protection depends on the flow velocities associated with the spillway design flood and energy dissipation required. Riprap is the preferred form of outlet protection when designed according to **Chapter 5** of this handbook and the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition. Gabion baskets are also an acceptable outlet protection material. Other references for designing outlet protection include publications by the Federal Highway Administration, the Soil Conservation Service, the Bureau of Reclamation and the U.S. Army Corps of Engineers.

The following general criteria are recommended for the placement of riprap at the outfall of a stormwater impoundment:

1. The bottom of the riprap apron should be constructed at 0% slope along its length. The end of the apron should match the grade and alignment of the receiving channel.

2. If the receiving channel is well-defined, the riprap should be placed on the channel bottom and side slopes (no steeper than 2:1) for the entire length, $L_a$, required per **Chapter 5** and the VESCH, 1992 edition. Riprap placement should not alter the channel's geometry. Excavation of the channel bed and banks may be required to construct the full thickness of the apron.

3. If the barrel discharges into the receiving channel at an angle, the opposite bank must be protected up to the 10-year storm elevation. In no instance should the total length of outlet protection be shortened. If a permit requires that no work may be performed in the stream or channel, then the outlet structure should be moved back to allow for adequate protection.

4. The horizontal alignment of the apron should have no bends within the design length, La. Additional rip rapshould be placed if a significant change in grade occurs at the downstream end of the outfall apron.

5. Filter fabric should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap.

Trash Racks and Debris Control Devices

Most basins will collect a certain amount of trash and debris from incoming flows. Floating debris such as grass clippings, tree limbs, leaves, trash, construction debris, and sediment bed load from upstream watersheds are common. Therefore, all control structures, including detention, extended-detention and retention basin low-flow weirs and orifices should have a trash rack or debris control device. The following are recommended design criteria for trash racks and debris control devices:

1. Openings for trash racks should be no larger than one-half of the minimum conduit dimension, and to discourage child access, bar spacing should be no greater than 1 foot apart. The clear distance between the bars on large storm discharge openings should generally be no less than 6 inches.

2. **Flat grates for trash racks are not acceptable**. Inlet structures that have flow over the top should have a non-clogging trash rack such as a hood-type inlet that allows passage of water from underneath the trash rack into the riser, or a vertical or sloped grate. The designer should verify that the surface area of the vertical perimeter of a raised grate equals the area of the horizontal top opening. This will allow adequate flow passage should the top horizontal surface become clogged. Examples are shown in **Figure 3.02-5**.

3. Metal trash racks and monitoring hardware should be constructed of galvanized or stainless steel metal.

4. Methods to prevent clogging of extended detention orifices in dry extended detention basins should be carefully designed since these orifices are usually very small and located at the invert or bottom of the basin (refer to **Minimum Standard 3:07, Extended Detention Basin**).

<u>Anti-vortex Device</u>

All drop inlet spillways designed for pressure flow should have adequate anti-vortex devices. An anti-vortex device is not required if weir control is maintained in the riser through all flow stages, including the maximum design storm or safety storm.

An anti-vortex device may be a baffle or plate installed on top of the riser, or a headwall set on one side of the riser. Examples of anti-vortex devices are shown in **Figure 3.02-6**.

<u>Drain Pipes and Valves</u>

Stormwater management facilities having permanent impoundments may be designed so that the permanent pool can be drained to simplify maintenance and sediment removal. The draining mechanism will usually consist of a valve or gate attached to the spillway structure and an inlet pipe projecting into the reservoir area with a trash rack or debris control device. The typical configuration of a drainpipe will place the valve inside the riser structure with the pipe extending out to the pool area. This configuration results in the drain pipe being pressurized by the hydraulic head associated with the permanent pool. Pressurized drain pipes should consist of mechanical joints in order to avoid possible leaks and seepage resulting from this condition. In all cases, valves should be secured to prevent unauthorized draining of the facility.

Basin drains should be designed with sufficient capacity to pass the 1-year frequency design storm with limited ponding in the reservoir area, such that sediment removal or other maintenance functions are not hampered.

An uncontrolled or rapid drawdown of a stormwater basin could cause a slide in the saturated upstream slope of the dam embankment or shoreline area. Therefore, the design of a basin drain system should include specific operating instructions for the owner. **Generally, drawdown rates should not exceed 6 inches per day**. For embankments or shoreline slopes of clay or silt, drawdown rates as low as *1 inch per week* may be required to ensure slope stability. (FPFM, 1994).

Antiflotation

The design of a principal spillway riser structure should include a *flotation* or *buoyancy* calculation.

When the ground around the riser is saturated and the water surface elevation in the basin is higher than the riser footing, then the riser structure behaves like a “vessel” floating in water. Such flotation forces on the riser can lead to failure of the connection between the riser and barrel, and any other rigid connections.

The downward force of the riser and footing (assuming the riser is attached firmly to the footing) is the *structure weight.* To maintain adequate stability, this weight must be at least 1.25 times greater than the upward force, or buoyant force, acting on the riser.

**An *anti-flotation* calculation procedure is presented in Chapter 5.**

Maintenance and Safety

As mentioned previously, trash racks and debris control structures should be sized to prevent entry by children. Fencing or other barriers should be considered around spillway structures having open or accessible drops more than 3 feet. A locking manhole cover on the riser may also be prudent to prevent unauthorized access.

**FIGURE 3.02 - 5**
*Trash Rack*

**FIGURE 3.02 - 6**
*Anti-Vortex Device*

## Construction Specifications

The construction specifications for principal spillways outlined below should be considered as minimum guidelines. More stringent requirements may be needed depending upon individual site conditions. Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed.

Further guidance can be found in the SCS Engineering Field Manual. Specifications for the work should conform to the methods and procedures specified for installing earthwork, concrete, reinforcing steel, pipe water gates, metal work, woodwork, and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government. Final construction specifications should be included on the construction plans.

Corrugated Metal Pipe - The following criteria apply:

1. **Materials –** Corrugated metal pipe may be steel, aluminum coated steel or aluminum.

   a. *Steel Pipe* - This pipe and its appurtenances should be galvanized and fully bituminous coated and should conform to the requirements of AASHTO Specification M-190 Type A with watertight coupling bands. Any bituminous coating damaged or otherwise removed should be replaced with cold applied bituminous coating compound. Steel pipes with polymeric coatings should have a minimum coating thickness of 0.01 inches (10 *mils*) on both sides of the pipe. The following coatings or an approved equal may be used: Nexon, Plasti-Cote, Blac-Clad, and Beth-Cu-Loy. Coated corrugated steel pipe should meet the requirements of AASHTO M-245 and M-246.

   b. *Aluminum Coated Steel Pipe* - This pipe and its appurtenances should conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Any aluminum coating damaged or otherwise removed should be replaced with cold applied bituminous coating compound.

   c. *Aluminum Pipe* - This pipe and its appurtenances should conform to the requirements of AASHTO Specification M-196 or M-211 with watertight coupling bands or flanges. Aluminum surfaces that are to be in contact with concrete should be painted with one coat of zinc chromate primer. Hot dipped galvanized bolts may be used for connections. The pH of the surrounding soils should be between 4 and 9.

2. **Coupling bands, anti-seep collars, end-sections, etc.** - All connectors must be composed of the same material as the pipe. Metals must be shielded from dissimilar materials with rubber or plastic insulation at least 24 mils thick.

3. **Connections** - All connections to pipes must be completely watertight. The drain pipe (or barrel) connection to the riser should be welded all around when both are metal. Anti-seep collars should be connected to the pipe so that they are completely watertight. **Dimple bands are not considered watertight**.

   A rubber or neoprene gasket should be used when joining pipe sections. The end of each pipe should be re-rolled by enough corrugations to fit the band width. The following connection types are acceptable for pipes less than 24 inches in diameter: flanges with gaskets on both ends of the pipe, a 12-inch wide standard lap type band with a 12-inch wide by ½-inch thick closed cell circular neoprene gaskets, and a 12-inch wide hugger type band with 0-ring gaskets having a minimum diameter of 3/8 inches greater than the corrugation depth. Pipes 24 inches in diameter and larger should be connected by a 24-inch long annular corrugated band using rods and lugs and a 24 inch wide by 3/8 inch thick closed cell circular neoprene gasket. Helically corrugated pipe should have either continuous welded seams or lock seams with internal caulking or a neoprene bead.

   All pipe gaskets must be properly lubricated with the material provided by the pipe manufacturer, and tensioned. Flat gaskets must be factory welded or solvent glued into a circular ring, with no overlaps or gaps.

4. **Bedding** - The pipe should be firmly and uniformly bedded throughout its length. Where rock or soft, spongy or other unstable soil is encountered, it should be removed and replaced with suitable earth that is subsequently compacted to provide adequate support. Under no conditions should gravel bedding be placed under a conduit through the embankment.

5. **Backfill** - All backfill material and placement should conform to Structure Backfill specifications in **Minimum Standard 3.01, Earthen Embankment**.

<u>Reinforced Concrete Pipe</u> - The following criteria apply:

1. **Materials** - Reinforced concrete pipe should have bell and singular spigot joints with rubber gaskets and should equal or exceed ASTM Designation C-361.

2. **Bedding** - All reinforced concrete pipe conduits should be laid in a **concrete** bedding for their entire length. This bedding should consist of high slump concrete placed under the pipe and up the sides of the pipe at least 25% of its outside diameter, and preferrably to the spring line, with a minimum thickness of 3 inches, or as shown on the drawings.

3. **Laying pipe** - Bell and spigot pipe should be placed with the bell end upstream. Joints should be made per recommendations from the manufacturer. After the joints are sealed for the entire run of pipe, the bedding should be placed so that all spaces under the pipe are filled. Care should be taken to prevent any deviation from the original line and grade of the pipe.

4. **Backfill** - All backfill material and placement should conform to Structure Backfill specifications in **Minimum Standard 3.01, Earthen Embankment**.

<u>Polyvinyl Chloride (PVC) Pipe</u> - The following criteria apply:

1. **Materials** - PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241.

2. **Connections** - Joints and connections to anti-seep collars should be completely watertight.

3. **Bedding** - The pipe should be firmly and uniformly bedded throughout its length. Where rock or soft, spongy or other unstable soil is encountered, it should be removed and replaced with suitable earth that is subsequently compacted to provide adequate support.

4. **Backfill** - All backfill material and placement should conform to Structure Backfill specifications in **Minimum Standard 3.01, Earthen Embankment**.

<u>Filters and Drainage Layers</u>

In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

Up to four feet of embankment material may placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12-inch lifts of filter material, flooded, and vibrated as described above, until the top of adjacent fill is reached.

**Filter fabrics should not be used in lieu of sands and gravel layers within the embankment**.

**TABLE 3.02 - 1**
***Minimum Gages for Metal Pipes***

**CORRUGATED STEEL PIPE**
*2-2/3" x ½" Corrugations*

| Fill Height Over Pipe *(ft.)* | Pipe Diameter *(in.)* 24 & Less | 30 | 36 | 42 | 48 |
|---|---|---|---|---|---|
| 1 - 15 | 16 | 16 | 14 | 10 | 8 |
| 16 - 20 | 16 | 12 | 8 | * | * |
| 21 - 25 | 16 | 10 | * | * | * |

**CORRUGATED ALUMINUM PIPE**
*2-2/3" x ½" Corrugations*

| Fill Height Over Pipe *(ft.)* | Pipe Diameter *(in.)* 24 & Less | 24 | 30 | 36 |
|---|---|---|---|---|
| 1 - 15 | 16 | 14 | 10 | 8 |
| 16 - 20 | 12 | 10 | * | * |
| 21 - 25 | 10 | * | * | * |

**CORRUGATED STEEL PIPE**
*3" x 1" or 5" x 1" Corrugations*

| Fill Height Over Pipe *(ft.)* | Pipe Diameter *(in.)* 36 | 42 | 48 | 54 | 60 | 66 | 72 |
|---|---|---|---|---|---|---|---|
| 1 - 15 | 16 | 16 | 16 | 16 | 14 | 12 | 10 |
| 16 - 20 | 16 | 16 | 14 | 10 | 8 | * | * |
| 21 - 25 | 16 | 14 | 10 | 8 | * | * | * |

* Not permitted
Coatings for corrugated steel should be as specified in this handbook, or equivalent.

**CORRUGATED ALUMINUM PIPE**
*3" x 1" Corrugations*

| Fill Height Over Pipe *(ft.)* | Pipe Diameter *(in.)* 30 | 36 | 42 | 48 | 54 |
|---|---|---|---|---|---|
| 1 - 15 | 16 | 16 | 14 | 10 | 8 |
| 16 - 20 | 16 | 12 | 8 | * | * |
| 21 - 25 | 12 | 8 | * | * | * |

* Not permitted

*Source: SCS Standards and Specifications for Ponds - Code 378*

**TABLE 3.02 - 2**
***Acceptable PVC Pipe for Use in Earth Dams[1]***

| Nominal Pipe Size *(in.)* | Schedule or Standard Dimension Ration *(SDR)* | Maximum Depth of Fill Over Pipe *(ft.)* |
|---|---|---|
| 6 - 24 | Schedule 40<br>Schedule 80<br>SDR 26 | 10<br>15<br>10 |
| [1]Polyvinyl chloride pipe, PVC 1120 or PVC 1220, conforming to ASTM D-1785 or ASTM D-2241. | | |

*Source: SCS Standards and Specifications for Ponds - Code 378*

Concrete

Concrete should meet the requirements of the Virginia Department of Transportation (VDOT) Road and Bridge Specifications, latest edition.

Outlet Protection

Outlet protection should meet the requirements and construction specifications of the VESCH, 1992 edition, Std. & Spec. 3.18, Outlet Protection, and 3.19, Riprap, latest edition. Materials should conform to the following:

1. Filter fabric should meet or exceed the requirements in Standard & Specification 3.18 and 3.19 in the VESCH, 1992 edition.

2. Riprap should meet or exceed the requirements in Standard & Specification 3.18 and 3.19 in the VESCH, 1992 edition.

3. Gabion baskets should be made of hexagonal triple-twist mesh, PVC coated, heavily galvanized steel wire. The maximum linear dimension of the mesh opening should not exceed 4 1/2 inches and the area of the mesh opening should not exceed 10 square inches.

Stone or riprap for the baskets should be sized according to the following criteria:

**TABLE 3.02 - 3**
***Gabion Basket Criteria***

| BASKET THICKNESS | | STONE SIZE |
|---|---|---|
| *inches* | *millimeters* | *inches* |
| 6 | 150 | 3 - 5 |
| 9 | 225 | 4 - 7 |
| 12 | 300 | 4 - 7 |
| 18 | 460 | 4 - 7 |
| 36 | 910 | 4 - 12 |

The stone or riprap should consist of field stone or rough, unhewn quarry stone. The stone should be hard and angular and of a quality that will not disintegrate from exposure to water or weather. The specific gravity of the individual stones should be at least 2.5.

Recycled concrete may be used and will be considered equivalent if it has a density of at least 150 pounds per cubic foot and no exposed steel or reinforcing bars.

Trash Rack and Debris Control Devices

All trash rack and debris control components should be stainless steel or galvanized metal per the Virginia Department of Transportation (VDOT) specifications. Trash racks attached to a concrete spillway structure should be secured with stainless steel anchor bolts.

## Maintenance and Inspection Guidelines

This section presents general operation, maintenance and inspection guidelines for principal spillways and components. However, these guidelines are not intended to be all-inclusive. Specific structures may require special measures not discussed here. The engineer is responsible for determining what, if any, additional items are necessary.

1. Spillway structures should be cleared of debris periodically and after any significant rainfall event where inspection reveals a significant blockage.

2. During low water conditions, concrete spillway structures should be inspected to decide if water is passing through any joints or other structure contacts and to identify any cracks, spalling, broken or loose sections. Any cracked, spalled, broken or loose sections should be cleaned and refilled with an appropriate concrete patching material. A professional engineer should be consulted to repair extensive leakage, spalls or fractures.

3. Outlet protection (stilling basins) and discharge channels should be cleared of brush at least once per year.

4. Trash racks and locking mechanisms should be inspected and tested periodically to make sure they are intact and operative.

5. All sluice gates (or other types of gates or valves used to drain an impoundment) should be operated periodically to insure proper function. The gate and stem should be periodically lubricated and all exposed metal should be painted to protect it from corrosion.

6. Any repairs made to the principal spillway (riser or barrel) should be reviewed by a professional engineer. Vertical trenching to expose the barrel should not be allowed under any circumstances. The trench side slopes should be stepped back at a 2:1 slope, minimum.

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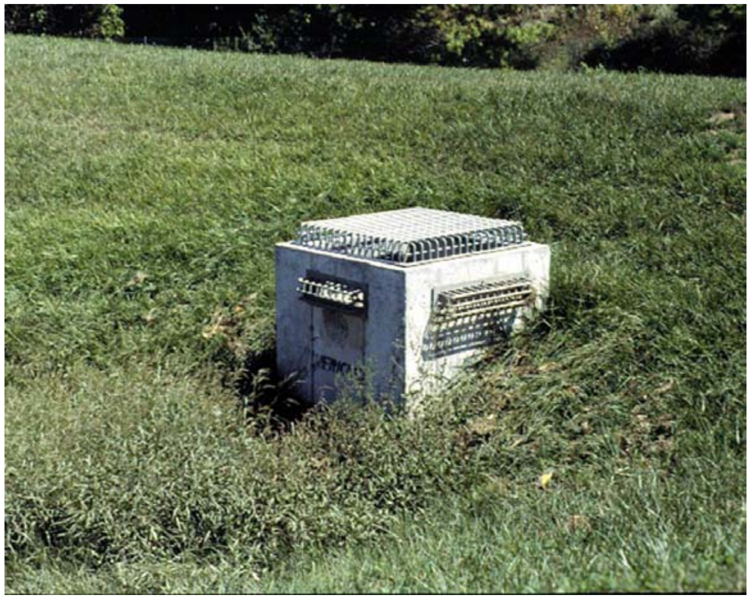


Principal Spillway multi-stage riser. Note bird-cage type trash rack to prevent clogging.

Principal Spillway multi-stage riser configured for temporary sediment basin function. Note anti-vortex plate and inclined trash rack to prevent clogging.

# Principal Spillway

Principal Spillway multi-stage riser – "V" shaped weir protected by trash rack.

Principal Spillway multi-stage weir. Note low flow/extended detention orifice protected by "hood" draws water from approximately 18" below pool surface.

# Principal Spillway

*MINIMUM STANDARD 3.03*

# VEGETATED EMERGENCY SPILLWAY

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.03

# VEGETATED EMERGENCY SPILLWAY

### Definition

A vegetated emergency spillway is an open channel, usually trapezoidal in cross-section, that is constructed beside an embankment. It consists of an *inlet channel*, a *control section,* and an *exit channel*, and is lined with erosion-resistant vegetation.

### Purpose

The purpose of a vegetated emergency spillway is to convey flows that are greater than the principal spillway's design discharge at a *non-erosive velocity* to an *adequate channel*.

### Conditions Where Practice

A vegetated emergency spillway is appropriate to use when the required maximum design flood volume exceeds the capacity of the principal spillway system. A vegetated emergency spillway may also be used as a safety feature to pass flood flows when or if the principal spillway becomes clogged.

### Planning Considerations

The *adjacent topography* (steepness of the abutments), the *existing or proposed land* use, and *other factors* (such as a roadway over the embankment) influence the design and construction of a vegetated emergency spillway.

**Vegetated emergency spillways must be built in existing ground or "cut."** Therefore, additional land disturbance beside the embankment must be accounted for during the planning stages of a project. Sometimes, an emergency spillway may not be practical due to this or other considerations.

***Remember, even though an emergency spillway helps to extend the life expectancy of an impoundment and lowers the associated downstream hazard conditions, it should not be located on any portion of the embankment fill.***

If site topography or other constraints preclude the use of a vegetated emergency spillway in "cut," the principal spillway can be oversized to pass the additional flows or an *armored* emergency spillway may be provided. A cost analysis may be helpful to aid in the selection of the spillway type. If armoring is chosen, riprap, concrete or any other permanent, nonerodible surface may be used. Note, however, that **an armored emergency spillway over the top of an embankment should be designed by a qualified professional**.

Vegetated emergency spillways should be used only where the soils and topography will permit safe discharge of the peak flow at a point downstream from the embankment and at a velocity that will not cause appreciable erosion. Additional flood storage in the reservoir may be provided to reduce the design flow or the frequency with which the spillway is used.

## Design Criteria

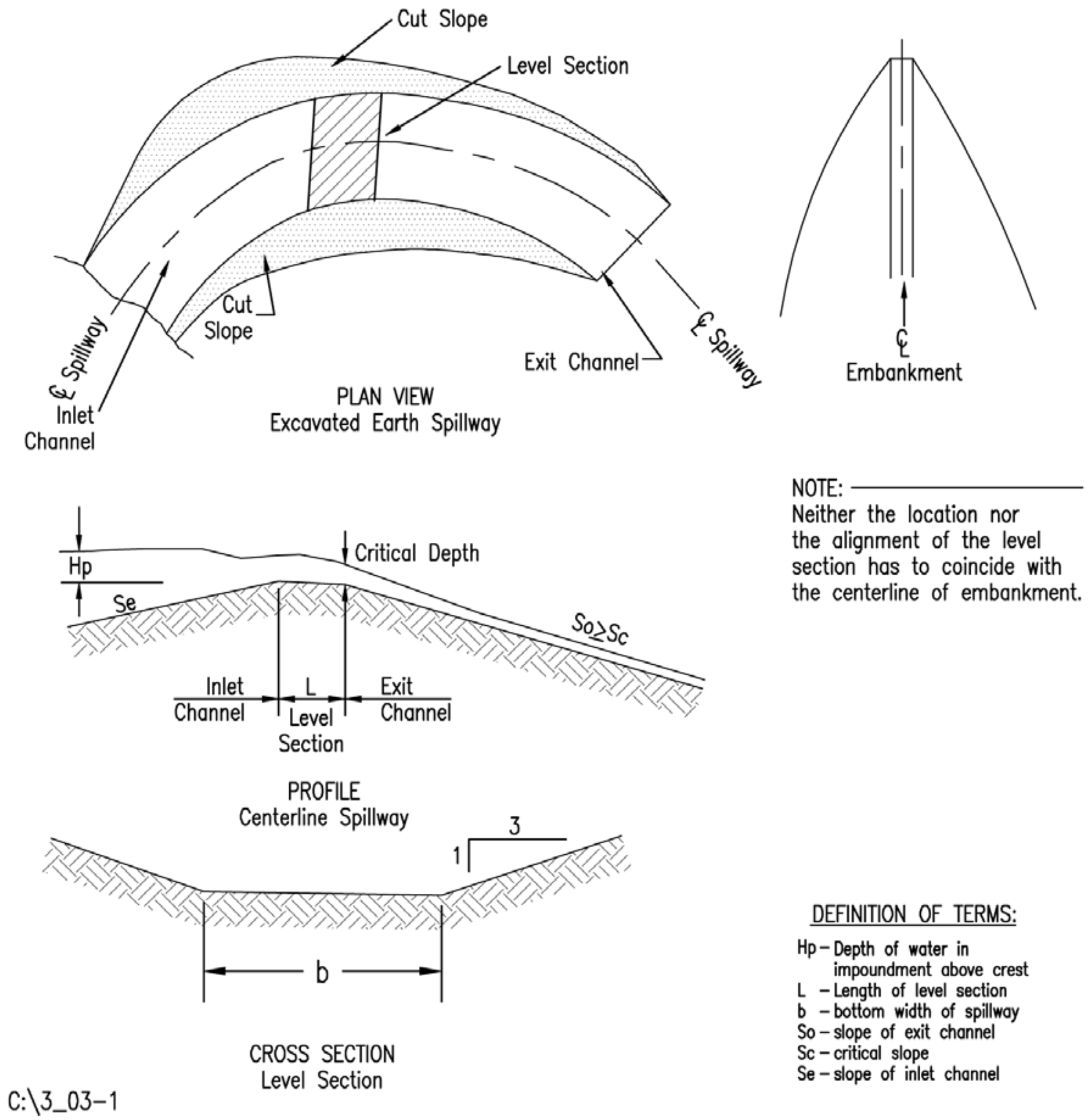
A vegetated emergency spillway is designed to convey a pre-determined design flood discharge without excessive velocities and without overtopping the embankment. **The maximum design water surface elevation through the emergency spillway should be at least 1 foot lower than the settled top of the embankment**.

Layout

Vegetated spillways should be constructed in undisturbed earth in the abutments at one or both ends of an earthen embankment or over a topographic saddle anywhere on the periphery of the basin. **The channel should be excavated into undisturbed earth or rock and the water surface, under maximum design flood discharge, should be confined by undisturbed earth or rock**.

Excavated spillways consist of three elements: 1) an *inlet channel*, 2) a *level section*, and 3) an *exit channel*. (See **Figure 3.03-1**.) Flow enters the spillway through the inlet channel. The depth of flow, $H_p$, located upstream from the level section, is controlled in the level section and then discharged through the exit channel. Flow in the inlet channel is *sub-critical*. Flow in the exit channel can be either *critical* or *supercritical*. **The control section is, therefore, the point on the spillway where the flow passes through critical depth**. It is recommended that the control section be installed close to the intersection of the earthen embankment and the emergency spillway centerlines.

**FIGURE 3.03 - 1**
***Typical Plan and Profiles Along the Centerline of an Earth Spillway***



The topography must be carefully considered when constructing an emergency spillway. The alignment of the exit channel must be straight to a point far enough below the embankment to insure that any flow escaping the exit channel cannot damage the embankment. This may result in additional clearing and/or grading requirements beside the abutments, property line, etc.

**Figure 3.03-1** shows profiles along the centerline of a typical vegetated spillway. To reduce losses through the inlet channel, the cross-sectional area of flow in the inlet channel should be large in comparison to the flow area at the control section. Where the depth of the channel changes to provide for the increased flow area, the bottom width should be altered gradually to avoid abrupt changes in the shape of the sloping channel banks.

The exit channel must have an adequate slope to discharge the peak flow within the channel. However, the slope must be no greater than that which will produce maximum permissible velocities for the soil type or the planned grass cover.

Soil Types and Vegetative Cover

The type of soil and vegetative cover used in an emergency spillway can be used to establish the spillway design dimensions (Procedure 2 - **Chapter 5-8**). Soil types are classified as *erosion resistant* and *easily erodible*. ***Erosion resistant soils*** are those with a high clay content and high plasticity. Typical soil textures for erosion resistant soils are silty clay, sandy clay, and clay. ***Easily erodible soils*** are those with a high content of fine sand or silt, and a low plasticity or non-plastic. Typical soil textures for easily erodible soils are fine sand, silt, sandy loam, and silty loam. **Table 3.03-1** provides permissible velocities for a vegetated spillway based on its soil type, vegetated cover, and exit channel slope. The maximum permissible velocity may be increased by 25% when the anticipated average use is less than once in 10 years.

***In general, it is recommended that a vegetated emergency spillway be designed to operate during the 100-year frequency storm or greater.***

The *type* and *length of vegetative cover* affect the design of a vegetated spillway. Vegetation provides a *degree of retardance* to the flow through the spillway. **Table 3.03-2** gives retardance values for various heights of vegetative cover. Retardance for a given spillway will depend mostly upon the *height* and *density* of the cover chosen. Generally, after the cover is selected, "retardance with a good, uncut condition" should be used to find the capacity. Since a condition offering less protection and less retardance exists during the establishment period and after mowing, a lower degree of retardance should be used when designing for stability. Refer to the sample exercises for the design of vegetated spillways found in **Chapter 5**.

Hydraulic Design

The hydraulic design of earthen spillways can be simplified if the effects of *spillway storage* are ignored. Stormwater facilities designed for compliance with state or local stormwater management regulations are typically small, resulting in minimal storage effects on the flood routing.

Two design calculation procedures are presented in **Chapter 5-8**. The first (Procedure 1) is a conservative design procedure which is also found in the Virginia Erosion & Sediment Control Handbook (VESCH) 1992 edition, (Std., & Spec. 3.14). This procedure is typically acceptable for stormwater management basins. The second method (Procedure 2) utilizes the roughness, or retardance, and durability of the vegetation and soils within the vegetated spillway. This second design is appropriate for larger or regional stormwater facilities where the construction inspection and permanent maintenance are more readily enforced. These larger facilities typically control relatively large watersheds and are located such that the stability of the emergency spillway is essential to safeguard downstream features.

If the inflow is known (from the post-developed condition hydrology) and either the desired maximum water surface elevation, or the approximate width of the proposed emergency spillway (established by the embankment geometry and the adjacent topography), then the relationship between $H_p$, the depth of flow through the emergency spillway, and b, the emergency spillway bottom width, can be established using design Procedure 1 (**Chapter 5-8**) and **Table 5-12**.

If the required discharge capacity, $Q$, permissible velocity, $V$ (see **Table 3.03-1**), degree of retardance, $C$ (see **Table 3.03-2**), and the natural slope of the exit channel, $s_o$ , are known, then the bottom width, $b$, of the level and exit sections and the depth of flow, $H_p$ , may be computed using design Procedure 2 (**Chapter 5-8**) and **Table 5-13**.

***Table 5-13(a-d) is not appropriate for bottom widths less than 8 feet*.**

The hydraulic design of a vegetated emergency spillway should comply with the following:

1. The maximum permissible velocity for vegetated spillways should be selected using **Table 3.03-1**.

2. The slope range of the exit channel provided in **Table 5-11**, **Chapter 5**, is a minimum slope range needed to insure ***supercritical*** flow in the exit channel.

3. Spillway side slopes should be no steeper than 3H:1V unless the spillway is excavated into rock.

4. For a given $H_p$ , a decrease in the exit slope from $s_o$, as given in **Table 5-11** of **Chapter 5**, decreases the spillway discharge, but increasing the exit slope from $s_o$ does not increase discharge.

5. The exit channel should have a straight alignment and grade and, at a minimum, the same cross-section as the control section.

6. The inlet channel should have a straight alignment and grade.

7. The selected bottom width of the spillway should not exceed 35 times the design depth of flow. Where this ratio of bottom width to depth is exceeded, the spillway is likely to be damaged by meandering flow and accumulated debris. Whenever the required bottom width of the spillway is excessive, consideration should be given to the use of a spillway at each end of the dam. The two spillways do not need to be of equal width if their total capacity meets design requirements. If the required discharge capacity exceeds the ranges shown in the referenced tables, or topographic conditions preclude the construction of the exit channel bottom using a slope that falls within the designated ranges, alternate design procedures should be used.

8. Vegetated emergency spillways should be designed for use with the 100-year frequency storm or greater.

## Construction Specifications

Overall, widely acceptable construction standards and specifications for a vegetated emergency spillway on an embankment, such as those developed by the USDA Soil Conservation Service or the U. S. Army Corps of Engineers, should be followed. Further guidance can be found in the SCS Engineering Field Manual and the National Engineering Handbook. Specifications for all earthwork and any other related work should conform to the methods and procedures that apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Installation of a vegetated emergency spillway consists of the following: a) *excavating the proper bottom width and side slopes according to the approved plan*, b) *backfilling with 12 inches of topsoil (minimum)*, and c) *stabilizing the area* following the VESCH, 1992 edition.

## Maintenance and Inspection Guidelines

The following maintenance and inspection guidelines are recommendations. The engineer must decide if additional criteria are needed based upon the size and scope of the facility.

1. Vegetated emergency spillway channels should be mowed concurrently with the embankment and should not be cut to less than 6 to 8 inches in height.

2. The emergency spillway approach and discharge channels should be cleared of brush and other woody growth periodically.

3. After any flow has passed through the emergency spillway, the spillway crest (control section) and exit channel should be inspected for erosion. All eroded areas should be repaired and stabilized.

**TABLE 3.03 - 1**

***Permissible Velocities for Vegetated Spillways*** [1]

| Vegetative Cover | Permissible Velocity [2] *(ft/s)* | | | |
|---|---|---|---|---|
| | Erosion Resistant Soils [3] | | Easily Erodible Soils [4] | |
| | Slope of Exit Channel | | Slope of Exit Channel | |
| | *0-5%* | *5-10%* | *0-5%* | *5-10%* |
| Bermuda Grass<br>Bahiagrass | 8 | 7 | 6 | 5 |
| Buffalograss<br>Kentucky Bluegrass<br>Smooth Bromegrass<br>Tall Fescue<br>Reed Canary Grass | 7 | 6 | 5 | 4 |
| Sod Forming Grass-Legume Mixtures | 5 | 4 | 4 | 3 |
| Lespedeza<br>Weeping Lovegrass<br>Yellow Bluestem<br>Native Grass Mixtures | 3.5 | 3.5 | 2.5 | 2.5 |

[1] SCS-TP-61

[2] Increase values 25 percent when the anticipated average use of the spillway is not more frequent than once in 10 years.

[3] Those with a high clay content and high plasticity. Typical soil textures are silty clay, sandy clay, and clay.

[4] Those with a high content of fine sand or silty and lower plasticity or non-plastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

*Source - USDA-SCS Engineering Field Manual*

**TABLE 3.03 - 2**
***Retardance Classifications for Vegetative Channel Linings***

| Retardance | Vegetative Cover | Stand | Condition |
|---|---|---|---|
| B | Tall Fescue | Good | Unmowed - 18" |
| | Sericea Lespedeza | Good | Unmowed - 18" |
| | Grass-Legume Mixture | Good | Unmowed - 20" |
| | Small Grains, Mature | Good | Uncut - 19" |
| | Bermuda Grass | Good | Tall - 12" |
| | Reed Canary Grass | Good | Mowed - 14" |
| C | Bermuda Grass | Good | Mowed - 6" |
| | Redtop | Good | Headed - 18" |
| | Grass-Legume Mixture - Summer | Good | Unmowed - 7" |
| | Kentucky Bluegrass | Good | Headed - 9" |
| | Small Grains, Mature | Poor | Uncut - 19" |
| | Tall Fescue | Good | Mowed - 6" |
| D | Bermuda Grass | Good | Mowed - 2.5" |
| | Red Fescue | Good | Headed - 15" |
| | Grass-Legume Mixture, Spring and Fall | Good | Unmowed - 5" |
| | Sericea Lespedeza | Good | Mowed - 2" |

*Source: USDA-SCS*

## REFERENCES


USDA Soil Conservation Service. Engineering Field Manual.

USDA Soil Conservation Service. National Engineering Handbook.

USDA Soil Conservation Service. Technical Release No. 60, Earth Dams and Reservoirs.

U. S. Department of the Interior. Design of Small Dams. 1987.

Virginia Department of Conservation and Recreation. Virginia Erosion and Sediment Control Handbook (VESCH) 1992 edition.

Emergency Spillway “cut” into existing grade.

Emergency Spillway draining into concrete channel to protect embankment from erosion.

# Vegetated Emergency Spillway

*MINIMUM STANDARD 3.04*

# SEDIMENT FOREBAY

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# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.04

# SEDIMENT FOREBAY

### Definition

A sediment forebay is a settling basin or plunge pool constructed at the incoming discharge points of a stormwater BMP.

### Purpose

The purpose of a sediment forebay is to allow sediment to settle from the incoming stormwater runoff before it is delivered to the balance of the BMP. A sediment forebay helps to isolate the sediment deposition in an accessible area, which facilitates BMP maintenance efforts.

### Condition Where Practice Applies

A sediment forebay is an essential component of most impoundment and infiltration BMPs including retention, detention, extended-detention, constructed wetlands, and infiltration basins.

### Planning Considerations

A sediment forebay should be located at each inflow point in the stormwater BMP. Storm drain piping or other conveyances may be aligned to discharge into one forebay or several, as appropriate for the particular site. Forebays should be installed in a location which is accessible by maintenance equipment.

Water Quality

A sediment forebay not only serves as a maintenance feature in a stormwater BMP, it also enhances the pollutant removal capabilities of the BMP. The volume and depth of the forebay work in concert with the outlet protection at the inflow points to dissipate the energy of incoming stormwater flows. This allows the heavier, course-grained sediments and particulate pollutants to settle out of the runoff. **Note that for the BMPs listed in this handbook, the target pollutant removal efficiencies have been established assuming sediment forebays are included in the design**. Therefore, no additional pollutant removal efficiency is warranted for using a sediment forebay.

Channel Erosion Control and Flood Control

An "on line" BMP designed for flood control and channel erosion control is subject to the natural bed material (sediment) load, plus any bed load increases due to higher velocities in the upstream channels. This is especially true for regional facilities where the upstream channel is used to convey the increased developed condition flows. In such cases, the sediment forebay becomes an essential facility maintenance component since it serves to simplify clean-out operations.

Studies indicate that a well-designed retention basin will function for 20 to 25 years before it needs dredging. This implies a gradual sediment accumulation process. A concern regarding stormwater basins is that the landowners will probably change at least once during that 20 to 25-year period. The new owners may not be aware of the maintenance requirements and, may therefore, neglect to maintain the facility. Sediment will then continue to accumulate and will eventually fill the BMP pool volume.

A sediment forebay, however, is designed to trap the sediments within a confined area. This causes a more rapid sediment accumulation. Studies indicate that for a typical mixed-use watershed, sediment removal from the forebay should occur every 3 to 5 years. Despite this frequency, removal of sediment from the forebay should be less costly over the same time period than a one time cleaning of the entire basin. This is due in part to the fact that removing sediment from the forebay is a much simpler operation than that of an entire stormwater basin or pond. The sediment is confined to strategic forebay locations with easy access. Furthermore, the more frequent and less expensive schedule will likely become a regular part of the operation and maintenance efforts of the owners.

## Design Criteria

The most attractive aspect of a sediment forebay is its isolation from the rest of the facility. To create this separation, an earthen berm, or a gabion, concrete, or riprap wall can be constructed along the outlet side of the forebay. A designed overflow section should be constructed on the top of the separation to allow flow to exit the forebay at non-erosive velocities during the 2-year and 10-year frequency design storms. The overflow section may be set at the permanent pool elevation or the extended-detention volume elevation. It may also be designed to serve as a spillover for the forebay if the forebay is set at a higher elevation than the second or remaining cell.

The use of an aquatic bench with emergent vegetation around the perimeter will help with water quality as well as provide a safety feature for large forebays (used on large lake BMPs or retrofits).

Volume

The sediment forebay should be sized to hold 0.25 inches of runoff per impervious acre of contributing drainage area, with an absolute minimum of 0.1 inches per impervious acre. The volume of the sediment forebay is not in addition to the required volume of the retention basin permanent pool, but rather as part of the required pool volume. For dry facilities, the forebay does not represent available storage volume if it remains full of water. A dry forebay must be carefully designed to avoid the resuspension of previously deposited sediments. The 0.1 to 0.25 impervious watershed inches is guidance for ideal performance. For smaller stormwater facilities, a more appropriate sizing criteria of 10% of the total required pool or detention volume may be more practical. This volume should be 4 to 6 feet deep to adequately dissipate turbulent inflow without resuspending previously deposited sediment (Center for Watershed Protection, 1995).

Maintenance

Direct access to the forebay should be provided to simplify maintenance. Provision of a hardened access or staging pad adjacent to the forebay is also beneficial. Such an area helps protect the forebay and basin from excessive erosion resulting from operation of the heavy equipment used for maintenance. The pad area can be hardened by installing block pavers or similar material. Also, a hardened bottom to the forebay will help avoid over excavation during clean out operations.

In addition, a fixed, vertical, sediment depth marker should be installed in each sediment forebay to measure the sediment deposition. The sediment depth marker will allow the owner to monitor the accumulation and anticipate maintenance needs. Clean out frequency will vary depending on the conditions of the upstream watershed and the given site.

In general, sediment should be removed from the forebay every 3 to 5 years, or when 6 to 12 inches have accumulated, whichever comes first. To clean the forebay, draining or pumping and a possible temporary partial drawdown of the pool area may be required. Refer to the VESCH, 1992 edition for proper dewatering methods.

To reduce costs associated with hauling and disposing of dredged material, a designated spoil area should be approved and identified on the site during initial design and development of the project.

**FIGURE 3.04 - 1**
***Typical Sediment Forebay Plan and Section***

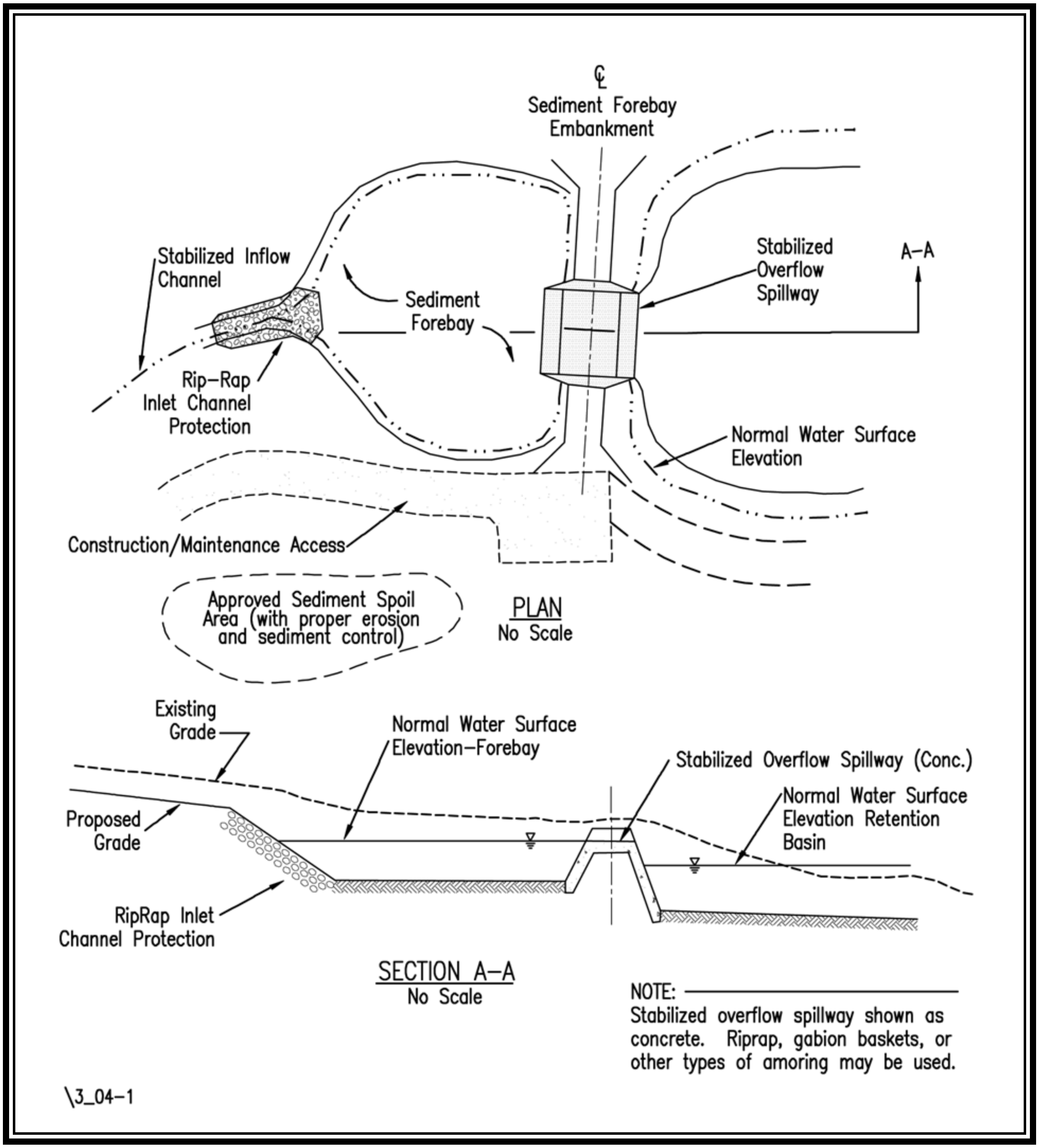
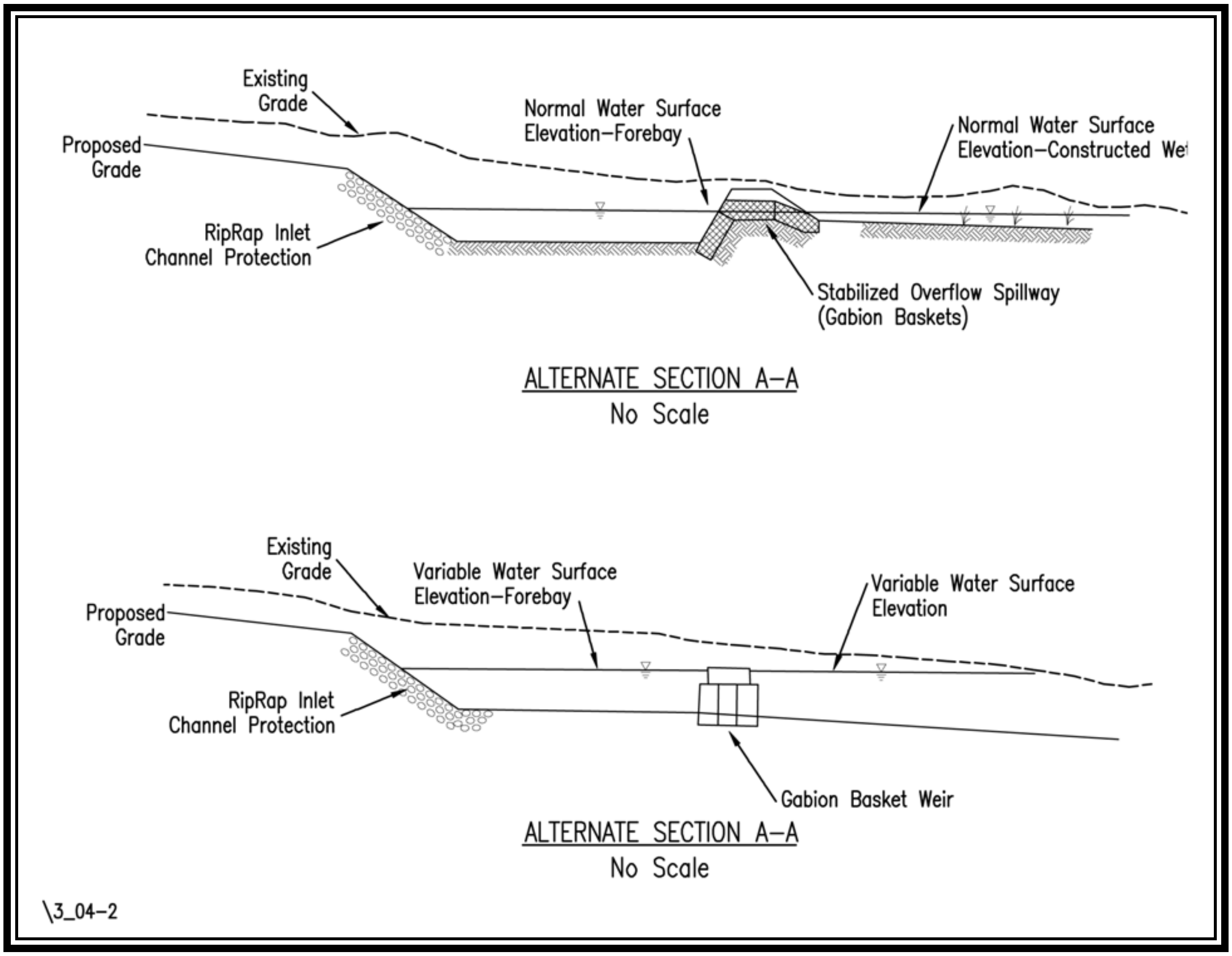


**FIGURE 3.04 - 2**
***Typical Sediment Forebay Sections***



Sediment Forebay constructed with earthen embankment and rip-rap overflow.

Sediment Forebay constructed with submerged rip-rap weir.

# Sediment Forebay

## *MINIMUM STANDARD 3.05*

# LANDSCAPING

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# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.05

# LANDSCAPING

### Definition

Landscaping is the placement of vegetation in and around stormwater management BMPs.

### Purpose

The purpose of landscaping is to help stabilize disturbed areas, enhance the pollutant removal capabilities of a stormwater BMP and improve the overall aesthetics of a stormwater BMP.

### Conditions Where Practice Applies

A landscape plan is an integral part of any land development project. It provides guidance and specifications for the type, location, and number of planting units according to the various requirements of the development project. A landscape plan may need one or all of the following:

1. Minimum green space or other requirements per local zoning or stabilization ordinances.

2. Natural and manmade vegetative buffer requirements between differing land uses or between developed land and natural resources.

3. Landscaping and stabilization requirements for stormwater management BMPs.

This minimum standard focuses on landscaping and stabilization requirements for stormwater management BMPs and their associated buffer areas. This standard may also be appropriate for other landscaping applications used in plan and specification preparation.

Certain BMPs, such as constructed wetlands, retention basins with an aquatic bench, *enhanced* extended detention basins with a shallow marsh, bioretention facilities, etc., require very specific plant materials and handling specifications. Refer to the minimum standards found in this chapter for additional criteria applicable to specific BMP designs.

Landscaped areas can provide significant reductions in pollutant export from developed sites through biological uptake of nutrients, sediment trapping, filtering, and infiltration.

For stormwater management purposes, landscaping is considered an integral component of a structural BMP. While the benefit realized from landscaping may be difficult to measure, it is widely accepted that the biological processes occurring in detention and retention BMPs are greatly enhanced by using vegetation. **The target pollutant removal efficiencies assigned to the BMPs in this handbook are based on the use of vegetative practices within the BMP buffer areas and the various BMP planting zones**. The vegetative practices should be specified in a landscape plan as part of the overall BMP and site construction documents.

## Planning Considerations

Plant selection should be based on the planting zones within the BMP. Various zones exist within a stormwater impoundment and each represents a different inundation frequency and soil moisture condition. The planting zones can be classified as follows:

*Zone 1: Deep Water Areas*: This zone is submerged beneath 18 inches to 6 feet of water. It supports submerged aquatic vegetation such as pondweed, coontail, wild celery, etc., and floating vegetation such as duckweed. Plants can actively remove metals from the water and provide food and habitat for invertebrates at the bottom of the food cycle. This zone may be present in retention basins, constructed wetlands, and in sediment forebays and micro-pools of extended-detention and *enhanced* extended-detention basins.

*Zone 2: Shallow Water Area*: This zone is 0 to 18 inches in normal depth and is the primary area for the establishment of emergent wetland plants. It may be present in retention basins, constructed wetlands, and *enhanced* extended-detention basins. This zone is divided into **low-marsh** and **high-marsh** sub-zones. The low-marsh extends from 6 to 18 inches in depth below the normal water surface. The high-marsh ranges from 6 inches below the normal water surface and up to the normal water surface. Vegetation in this zone can serve the following purposes:

- enhances nutrient uptake,
- reduces flow velocities to increase the rate of sediment deposition,
- reduces resuspension of bottom sediments,
- provides food and cover for wildlife,
- provides habitat for predatory insects and to serve as a check for mosquitoes,
- reduces shoreline erosion, and
- improves aesthetics

Suggested plants for this zone include common three-square, soft-stem bulrush, pickerelweed, arrow arrum, sedges, and others.

Zone 3: Shoreline Fringe: This zone is regularly inundated during runoff-producing storm events and may remain saturated due to the proximity of the permanent pool. However, plants must be tolerant of periodic drying, especially during the summer months. This zone extends from the normal water surface to about 1 foot above the normal water surface for retention basins and constructed wetlands. It also continues up to the maximum extended-detention volume elevation for extended-detention and *enhanced* extended-detention basins. The vegetation in this zone may serve the following purposes:

- stabilizes the shoreline,
- improves aesthetics,
- limits shoreline access by people and animals (geese),
- provides food, cover, and nesting for wildlife, and
- provides shade

Recommended species for this zone include herbaceous vegetation such as soft-stem bulrush, pickerelweed, rice cutgrass, sedges, and others. It also includes trees such as black willow and river birch and shrubs such as chokeberry.

Zone 4: Riparian Fringe Area: This zone is only briefly inundated during storms. It generally includes the upper storage areas of extended-detention basins (above the water quality or channel erosion control volume) and the lower basin areas of dry detention basins. It experiences both wet and dry soil conditions and periodic inundation. The vegetation in this zone may serve the following purposes:

- reduce resuspension of newly deposited sediments,
- prevent erosion, and
- provide habitat and food for wildlife,

A variety of trees, shrubs, and ground covers can be used in this zone, including black willow, river birch, red chokeberry, green ash, sweetgum and others.

Zone 5: Floodplain Terrace: This zone experiences inundation only during large storms. It is generally between the 2-year and 100-year water surface elevations. Plant species native to floodplains usually grow well in this zone. Plants selected for the floodplain terrace should have the following traits:

- ability to provide erosion control on steep slopes,
- ability to survive periodic mowing,
- ability to withstand exposure and compacted soil, and
- require minimal maintenance

Zone 6: Upland Areas: This zone seldom, if ever, experiences inundation and may include any buffer areas required for stormwater basins. Selection of plant species in this zone typically depends on local soil conditions and the intended secondary uses of the area. Refer to **Table 3.05-4** for a plant guide.

**Figure 3.05-1** shows a schematic cross-section of the six planting zones. Designers should select appropriate plant and tree species based on the characteristics of each zone, local soil conditions, sun and wind exposure levels, and intended secondary uses of the buffer area.

Preservation of Existing Vegetation

Although there are many reasons to minimize land disturbance associated with development, one of the greatest benefits may be the reduced runoff associated with undisturbed ground. Existing vegetation helps prevent erosion, filters runoff, and allows stormwater to filter into the ground, which ultimately results in lower stormwater management costs. As for the economics of site development, planning for the selective preservation of vegetation on a site **before land disturbance** is much less costly than trying to reestablish it once it has been removed. This holds true for both labor and replacement costs. In addition, studies conducted by the U.S. Forest Service and others indicate that preserving mature vegetation on residential sites can increase property values by 30% (NVPDC, 1996).

For guidance on non-structural BMPs and vegetative practices in general, refer to the following references:

- *Piedmont Provinces Vegetative Practices Guide, NVPDC, 1996.*
- *Nonstructural BMP Handbook: A Guide to Nonpoint Source Pollution Prevention Measures, NVPDC, 1996.*
- *Vegetative Practices Guide for Nonpoint Source Pollution Management, HRPDC, 1992.*
- *Chesapeake Bay Local Assistance Manual, CBLAD, 1989.*
- *Virginia Erosion & Sediment Control Handbook (VESCH), DCR, 1992.**

* The VESCH, 1992 edition, also provides details for tree preservation during construction.

## Design Criteria

The landscape plan for a stormwater BMP depends on the BMP being used. However, there are key components to any landscape plan which help assure its overall success. The following section describes these components.

A landscape plan for a stormwater management BMP should contain the following, at a minimum:

Plant Species Selection

Plants selected for a stormwater BMP must tolerate urban stresses such as pollutants, along with variable soil moisture and ponding fluctuations, climate, soils, and topography. Virginia has three distinct physiographic regions that reflect changes in soils and topography: Coastal Plain, Piedmont, and Appalachian and Blue Ridge regions. See **Figure 3.05-2**.

When selecting plants, native plant species should be used, if possible. Nonnative plants may require more care to adapt to the hydrology, climate, exposure, soil and other conditions. Also, some nonnative plants can become invasive, especially those used for stabilization, and may ultimately choke out the native plant population.

Newly constructed stormwater BMPs will be fully exposed for several years before the buffer vegetation becomes adequately established. Therefore, plants which require full shade, are susceptible to winter kill, or are prone to wind damage, should be avoided.

The plant material should conform to the American Standard for Nursery Stock, current issue, as published by the American Association of Nurserymen. The botanical (scientific) name of the plant species should be in accordance with the landscape industry's standard nomenclature. All plant material specified should be suited for USDA Plant Hardiness zones 6 or 7. See **Figure 3.05- 3**.

Transport and Storage of Plant Material

Specifications may be required for the handling and storage of certain plant materials. Aquatic or emergent plants, for example, require very precise instructions for the contractor. Depending on the time of year and the sequence of construction, it may not be prudent to deliver the plants to the site until the project is ready for landscaping.

Sequence of Construction

The *sequence of construction* describes the site preparation activities such as grading, addition of soil amendments, and any preplanting requirements. It also addresses the installation of erosion and sediment control measures, which should be in place until the entire landscape plan is implemented and the site is stabilized.

Installation of Plant Material

The success of any landscape plan depends on the selection of the proper specifications that are subsequently implemented by the contractor. The specifications should include procedures for installing the plants. They should also provide details for the steps to be taken before and after installation, such as any special instructions for the preparation of the planting pit and fertilization requirements. Any seasonal requirements for installation should also be specified. Typically, containerized or balled and burlapped trees or shrubs should be planted between March 15 and June 30, or between September 15 and November 15.

**The placement of trees or shrubs on an embankment is prohibited**. The root system of large trees and shrubs can threaten the structural integrity of the embankment and possibly cause its failure.

The side slopes of detention and retention BMPs are usually compacted during the construction process to ensure stability. The density of these compacted soils is often such that plant roots cannot penetrate to an adequate depth, leading to premature mortality or loss of vigor. Therefore, it is advisable to excavate oversized holes around the proposed planting sites and backfill with uncompacted topsoil. In general, planting holes should be 3 times deeper and wider than the diameter of the root ball (B&B stock) and 5 times deeper and wider for container-grown stock (MWCOG, 1992).

Contractor Responsibilities

The contractor should conform to any specifications that directly affect his aspect of the work. He should be aware that there may be penalties for unnecessarily delayed work, minimum success rate of plantings, etc.

For projects involving bio-retention basins or constructed wetlands, it may be advisable to utilize a subcontractor who specializes in aquatic landscaping. The plant specifications, handling, and installation procedures can be unusual compared to traditional landscaping requirements.

Maintenance

A maintenance schedule should be provided in the project plans and/or specifications. This is particularly important for BMPs that have a vegetative component that is integral to the pollutant removal efficiency. The schedule should include guidance regarding methods, frequency, and time of year for landscape maintenance and fertilization.

Specific plant communities may require different levels of maintenance. Upland and floodplain terrace areas, grown as meadows or forests, require very little maintenance, while aquatic or emergent vegetation may need periodic thinning or reinforcement plantings. Note that after the first growing season it should be obvious if reinforcement plantings are needed. If they are, they should be installed at the onset of the second growing season after construction.

Research indicates that for most aquatic plants the uptake of pollutants are stored in the roots, not the stems and leaves (Lepp 1981). Therefore, aquatic plants should not require harvesting before winter plant die-back. There are still many unanswered questions about the long term pollutant storage capacity of plants. It is possible that aquatic and emergent plant maintenance recommendations may be presented in the future.

**FIGURE 3.05 - 1**
***Planting Zones for Typical Stormwater BMPS***

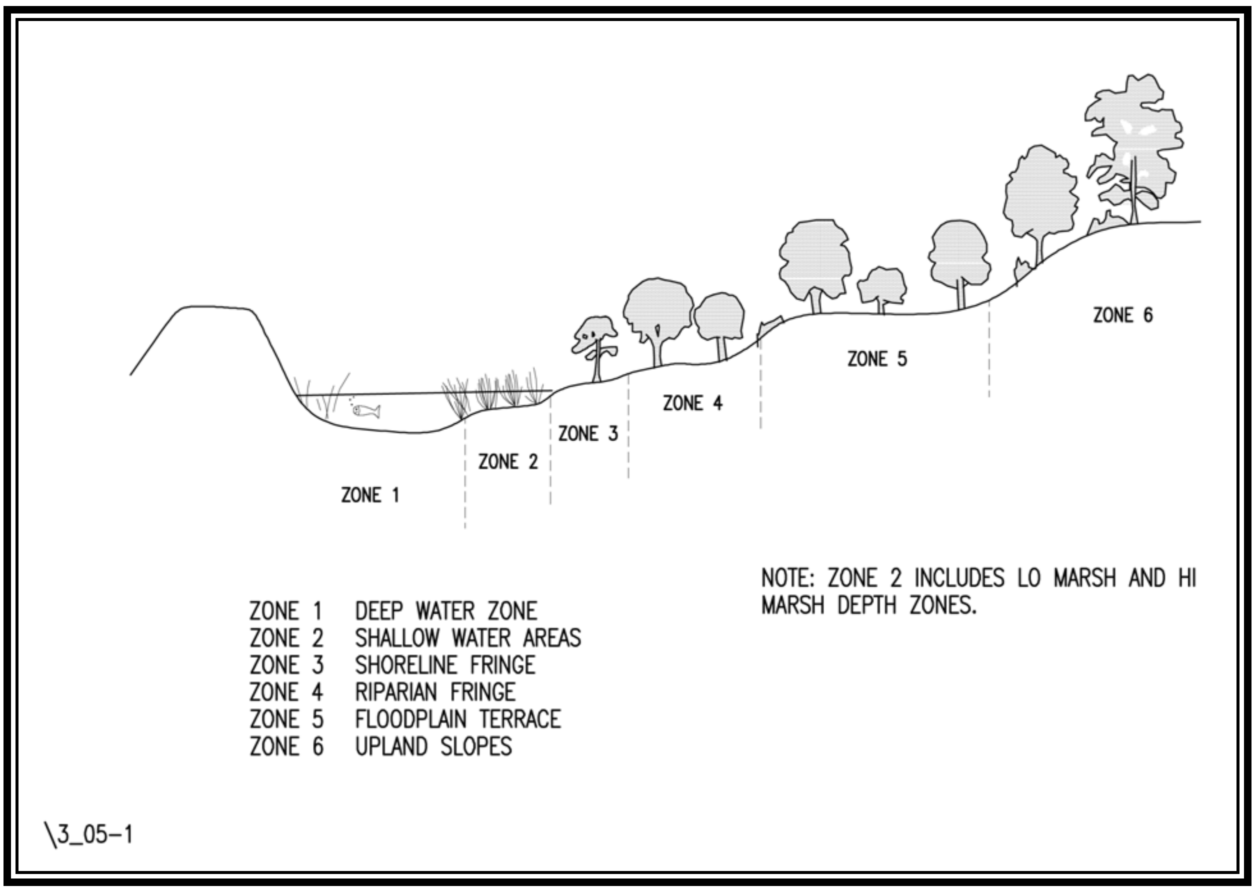

**FIGURE 3.05 - 2**
*Virginia Physiographic Regions*

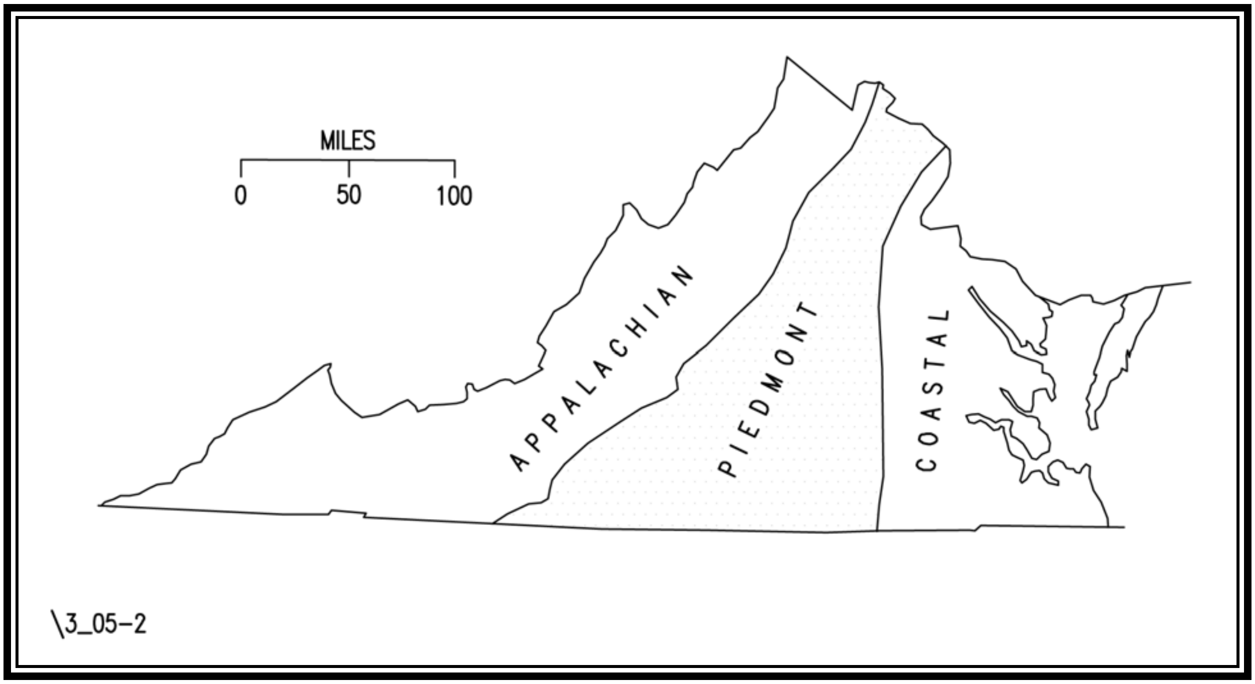

**FIGURE 3.05 - 3**
***USDA Plant Hardiness Zones***

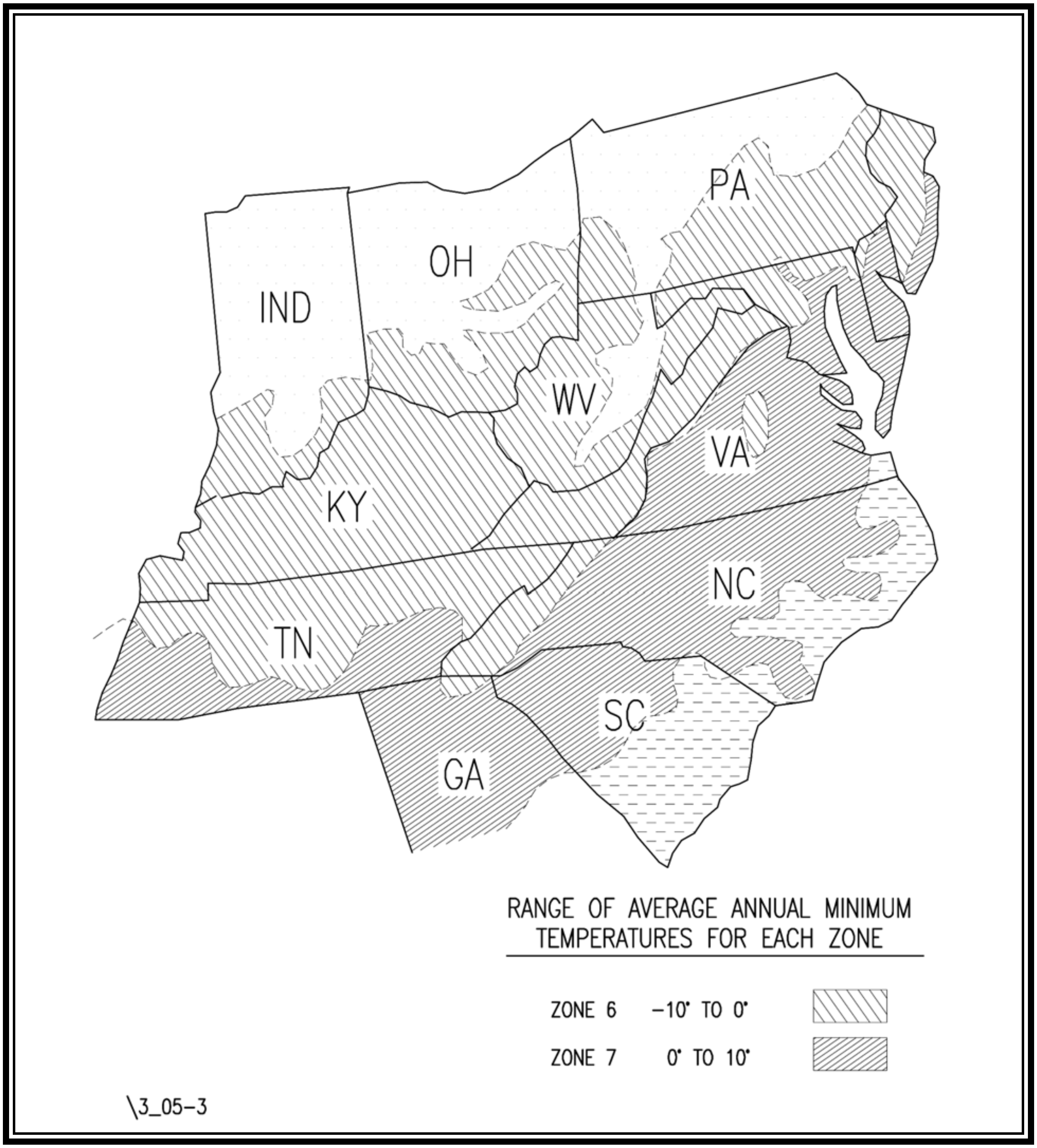

**FIGURE 3.05 - 4a**
***Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic, USA***
***Trees and Shrubs***

| Tree/Shrub | *Zone | Form | Available | Inundation Tolerance | Wildlife Value | Notes |
|---|---|---|---|---|---|---|
| American Beech *(Fagus grandifolia)* | 5,6 | Dec. Tree | no | no | High, mammals and birds. | Prefers shade and rich, well-drained soils. |
| American Holly *(Ilex opaca)* | 5,6 | Dec. Tree | yes | some | High,songbirds, food, cover, nesting. | Coastal plain only. Prefers shade and rich soils. |
| American Hornbeam *(Carpinus caroliniana)* | 4,5 | Dec. Tree | yes | yes | Moderate, food, browsing. | Most common in flood plains and bottom land of Piedmont and mountains. |
| Arrowwood Viburnum *(Viburnum dentatum)* | 2,3,4 | Dec. Shrub | yes | no | High, songbirds and mammals. | Grows best in sun to partial shade. |
| Bald Cypress *(Taxodium distichum)* | 3,4 | Dec. Tree | yes | yes | Little food value but good perching site for waterfowl. | Forested Coastal Plain wetlands. North of normal range. Tolerates drought. |
| Bayberry *(Myricia pensylvanica)* | 4,5,6 | Dec. Shrub | yes | no | High, nesting, food cover. Berries last into winter. | Coastal Plain only. Roots fix N. Tolerates slightly acidic soil. |
| Bitternut Hickory *(Carya cordiformis)* | 3,4,5 | Dec. Tree | no | yes | High, food. | Moist soils or wet bottom land areas. |
| Black Cherry *(Prunus serotina)* | 5,6 | Dec. Tree | yes | yes | High, fruit is eaten by many birds. | Temporarily flooded forested areas. Possible fungus infestation. |
| Black Walnut *(Juglans nigra)* | 5,6 | Dec. Tree | yes | yes | High, food. | Temporarily flooded wetlands along flood plains. Well drained, rich soils. |
| Blackgum or Sourgum *(Nyssa sylvatica)* | 4,5,6 | Dec. Tree | yes | yes | High, songbirds, egrets, herons, raccoons, owls. | Can be difficult to transplant. Prefers sun to partial shade. |
| Black Willow *(Salix nigra)* | 3,4,5 | Dec. Tree | yes | yes | High, browsing and cavity nesters. | Rapid growth, stabilizes stream banks. Full sun. |
| Buttonbush *(Cephalanthus occidentalis)* | 2,3,4,5 | Dec. Shrub | yes | yes | High, ducks and shorebirds. Seeds, nectar and nesting. | Full sun to partial shade. Will grow in dry areas. |
| Chestnut Oak *(Quercus prinus)* | 5,6 | Dec. Tree | no | no | High. Cover, browse and food. | Gypsy moth target. Dry soils. |

## FIGURE 3.05 - 4a (cont.)

| Tree/Shrub | *Zone | Form | Available | Inundation Tolerance | Wildlife Value | Notes |
|---|---|---|---|---|---|---|
| Common Choke Cherry *(Prunus virginiana)* | 5,6 | Dec. Tree | no | some | High, birds, mammals. Fruit and cover. | Prefers drier conditions. |
| Common Spicebush *(Lindera benzoin)* | 4,5 | Dec. Shrub | yes | no | Very high, songbirds. | Shade and rich soils. Tolerates acidic soils. Good understory species. |
| Eastern Cottonwood *(Populus deltoides)* | 4,5 | Dec. Tree | yes | yes | Moderate, cover, food. | Shallow rooted, subject to windthrow. Invasive roots. Rapid growth. |
| Eastern Hemlock *(Tsuga conadensis)* | 5,6 | Conif. Tree | yes | yes | Moderate. Mostly cover and some food. | Tolerates all sun/shade conditions. Tolerates acidic soil. |
| Eastern Red Cedar *(Juniperus virginiana)* | 4,5,6 | Conif. Tree | yes | no | High. Fruit for birds. Some cover. | Full sun to partial shade. Common in wetlands, shrub bogs and edge of streams. |
| Elderberry *(Sambucus canadensis)* | 4,5,6 | Dec. Shrub | yes | yes | Extremely high for food and cover, for birds and mammals. | Full sun to partial shade. |
| Flowering Dogwood *(Cornus florida)* | 4,5,6 | Dec. Tree | no | yes | High, birds, food. | Prefers rich, moist soils. Dogwood anthracnose possible problem. |
| Fringe Tree *(Chionanthus viginicus)* | 3,4,5 | Dec. Shrub or small tree | yes | some | Moderate. Food and cover. | Full sun to partial shade. Tolerates acidic soil. |
| Green Ash, Red Ash *(Fraxinus pennysylvanica)* | 4,5 | Dec. Tree | yes | yes | Moderate, songbirds. | Rapid growing stream bank stabilizer. Full sun to partial shade. |
| Hackberry *(Celtis occidentalis)* | 5,6 | Dec. Tree | yes | yes | High, food and cover. | Full sun to partial shade. |
| Ironwood/ Hophornbeam *(Ostrya virginiana)* | 5,6 | Dec. Tree | yes | yes | Moderate, food and browse. | Tolerant of all sunlight conditions. |
| Larch, Tamarack *(Larix laricina)* | 3,4 | Conif. Tree | no | yes | Low, nest tree and seeds. | Rapid initial growth. Full sun, acidic boggy soils. |
| Loblolly Pine *(Pinus taeda)* | 5,6 | Conif. Tree | yes | yes | Moderate, food, nesting, squirrels. | Coastal Plain only. Tolerant of extreme soil conditions. |

## FIGURE 3.05 - 4a (cont.)

| Tree/Shrub | *Zone | Form | Available | Inundation Tolerance | Wildlife Value | Notes |
|---|---|---|---|---|---|---|
| Mountain Laurel *(Kalmia latifolia)* | 6 | Evergreen | no | some | Low, cover, and nectar. Foliage is toxic to cattle and deer. | Partial shade, acidic soils. |
| Persimmon *(Diospyros virginiana)* | 4,5,6 | Dec. Tree | yes | no | Extremely high, birds, mammals. | Not shade tolerant. Well-drained soils. |
| Pin Oak *(Quercus palustris)* | 4,5,6 | Dec. Tree | yes | yes | High, mast. Tolerates acidic soil. | Gypsy moth target. Prefers sun to partial shade. |
| Red Chokeberry *(Pyrus arbutifolia)* | 3,4,5 | Dec. Shrub | no | yes | Moderate, songbirds. | Bank stabilizer. Partial sun. |
| Red Maple *(Acer rubrum)* | 4,5,6 | Dec. Tree | yes | yes | High, seeds and browse. Tolerates acidic soil. | Rapid growth. |
| Red Oak *(Quercus rubra)* | 5,6 | Dec. Tree | yes | no | High, food and cover. | Gypsy moth target. Prefers well drained, sandy soils. |
| River Birch *(Betula nigra)* | 3,4 | Dec. Tree | yes | yes | Low, but good for cavity nesters. | Bank erosion control. Full sun. |
| Scarlet Oak *(Quercus coccinea)* | 3,4 | Dec. Tree | no | no | High, food and cover. | Gypsy moth target. Difficult to transplant. |
| Shadbush, Serviceberry *(Amelanchier canadensis)* | 5,6 | Dec. Tree | yes | yes | High, nesting, cover and food. Birds and mammals. | Prefers partial shade. Common in forested wetlands and upland woods. |
| Silky Dogwood *(Cornus amomum)* | 5,6 | Dec. Shrub | yes | yes | High, songbirds, mammals. | Shade and drought tolerant. Good bank stabilizer. |

***Source:* *Native Plant Pondscaping Guide - Watershed Restoration Sourcebook, Natalie Karouna, MWCOG***

****Zone 1:** Submergent Aquatic Vegetation*
****Zone 2:** Shallow Water Bench - 6-12 inches Deep*
****Zone 3:** Shoreline Fringe - Regularly Inundated Area*
****Zone 4:** Riparian Fringe - Periodically Inundated Area, Wet Soils*
****Zone 5:** Floodplain Terrace - Infrequently Inundated, Moist Soils*
****Zone 6:** Upland Slopes - Seldom or Never Inundated, Moist To Dry Soils*

**FIGURE 3.05 - 4b**
***Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic, USA***
***Wetland Plants***

| Wetland Plants | *Zone | Form | Available | Inundation Tolerance | Wildlife Value | Notes |
|---|---|---|---|---|---|---|
| Arrow arum *(Peltandra virginica)* | 2 | Emergent | yes | up to 1 ft. | High, berries are eaten by wood ducks. | Full sun to partial shade. |
| Arrowhead/Duck potato *(Saggitaria latifolia)* | 2 | Emergent | yes | up to 1 ft. | Moderate, tubers and seeds eaten by ducks. | Aggressive colonizer. |
| Broomsedge *(Andropogon virginianus)* | 2,3 | Perimeter | yes | up to 3 in. | High, songbirds and browsers. Winter food and cover. | Tolerant of fluctuating water levels and partial shade. |
| Cattail *(Typha spp.)* | 2,3 | Emergent | yes | up to 1 ft. | Low, except as cover. | Aggressive. May eliminate other species. Volunteer. High pollutant treatment. |
| Coontail *(Ceratophyllum demersum)* | 1 | Submergent | no | yes | Low, food, good habitat and shelter for fish and invertebrates. | Free floating SAV. Shade tolerant. Rapid growth. |
| Common Three Square *(Scipus pungens)* | 2 | Emergent | yes | up to 6 in. | High, seeds, cover, waterfowl, songbirds. | Fast colonizer. Can tolerate periods of dryness. Full sun. High metal removal. |
| Duckweed *(Lemna sp.)* | 1,2 | Submergent /Emergent | yes | yes | High, food for waterfowl and fish. | May biomagnify metals beyond concentrations found in water. |
| Lizard's Tail *(Saururus cernuus)* | 2 | Emergent | yes | up to 1 ft. | Low, except wood ducks. | Rapid growth. Shade tolerant. |
| Marsh Hibiscus *(Hibiscus moscheutos)* | 2,3 | Emergent | yes | up to 3 in. | Low, nectar. | Full sun. Can tolerate periodic dryness. |
| Pickerelweed *(Pontederia cordata)* | 2,3 | Emergent | yes | up to 1 ft. | Moderate, ducks, nectar for butterflies. | Full sun to partial shade. |
| Pond Weed *(Potamogeton pectinatus)* | 1 | Submergent | yes | yes | Extremely high, waterfowl, marsh and shore-birds. | Removes heavy metals. |
| Rice Cutgrass *(Leersia oryzoides)* | 2,3 | Emergent | yes | up to 3 in. | High, food and cover. | Full sun, although tolerant of shade. Shoreline stabilization. |

## FIGURE 3.05 - 4b (cont.)

| Wetland Plants | *Zone | Form | Available | Inundation Tolerance | Wildlife Value | Notes |
|---|---|---|---|---|---|---|
| Sedges *(Carex spp.)* | 2,3 | Emergent | yes | up to 3 in. | High, waterfowl, songbirds. | Many wetland and several upland species. |
| Soft-stem Bulrush *(Scipus validus)* | 2,3 | Emergent | yes | up to 1 ft. | Moderate, good cover and food. | Full sun. Aggressive colonizer. High pollutant removal. |
| Smartweed (Polygonum spp.) | 2 | Emergent | yes | up to 1 ft. | High, waterfowl, songbirds, seeds and cover. | Fast colonizer. Avoid weedy aliens such as P. Perfoliatum. |
| Spatterdock (Nuphar luteum) | 2 | Emergent | yes | up to 1.5 ft. | Moderate, for food but high for cover. | Fast colonizer. Tolerant of fluctuating water levels. |
| Switchgrass *(Panicum virgatum)* | 2,3,4, 5,6 | Perimeter | yes | up to 3 in. | High, seeds, cover. Waterfowl, songbirds. | Tolerates wet/dry conditions. |
| Sweet Flag *(Acorus calamus)* | 2,3 | Perimeter | yes | up to 3 in. | Low, tolerant of dry periods. | Tolerates acidic conditions. Not a rapid colonizer. |
| Waterweed *(Elodea canadensis)* | 1 | Submergent | yes | yes | Low. | Good water oxygenator. High nutrient, copper, manganese and chromium removal. |
| Wild Celery *(Valisneria americana)* | 1 | Submergent | yes | yes | High, food for waterfowl. Habitat for fish and invertebrates. | Tolerant of murkey water and high nutrient loads. |
| Wild Rice *(Zizania aquatica)* | 2 | Emergent | yes | up to 1 ft. | High, food. Birds. | Prefers full sun. |

***Source: Native Plant Pondscaping Guide - Watershed Restoration Sourcebook, Natalie Karouna, MWCOG***

****Zone 1:Submergent Aquatic Vegetation***
****Zone 2:Shallow Water Bench - 6-12 inches Deep***
****Zone 3:Shoreline Fringe - Regularly Inundated Area***
****Zone 4:Riparian Fringe - Periodically Inundated Area, Wet Soils***
****Zone 5:Floodplain Terrace - Infrequently Inundated, Moist Soils***
****Zone 6:Upland Slopes - Seldom or Never Inundated, Moist To Dry Soils***

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Landscaping – “rough” shoreline edge and aquatic bench provides improved pollutant removal and shoreline stabilization.

Landscaping – “manicured” landscape plan.  Note brick bulkhead to control shoreline erosion.

# Landscaping

*MINIMUM STANDARD 3.06*

# RETENTION BASIN

View BMP Images

# LIST OF ILLUSTRATIONS

# MINIMUM STANDARD 3.06

# RETENTION BASIN

## Definition

A retention basin is a stormwater facility which includes a permanent impoundment, or pool of water, and, therefore, is normally wet, even during non-rainfall periods. Inflows from stormwater runoff may be temporarily stored above this permanent pool.

## Purpose

A retention basin provides for long-term water quality enhancement of stormwater runoff. Stormwater inflows may also be temporarily stored above the permanent pool for downstream flood control and channel erosion control. A retention basin is considered one of the most reliable and versatile BMPs available.

### Water Quality Enhancement

High removal rates of particulate and soluble pollutants (nutrients) can be achieved in retention basins through *gravitational settling*, *biological uptake* and *decomposition*. When an even higher degree of pollutant removal efficiency is required, the basin can be ***enhanced*** by using various modifications relating to the size and design of the permanent pool.

Monitoring studies have shown sediment removal efficiencies to range from 50-90%, total phosphorus removal efficiencies to range from 30-90% and soluble nutrient removal efficiencies to range from 40-80%. (MWCOG, 1992). The design elements, physical characteristics, and monitoring techniques varied for each basin studied, which explains the wide range of efficiencies. The target pollutant removal efficiencies assigned to the different design options are presented in **Table 3.06-1**.

**FIGURE 3.06 - 1**
***Retention Basin - Plan & Section***

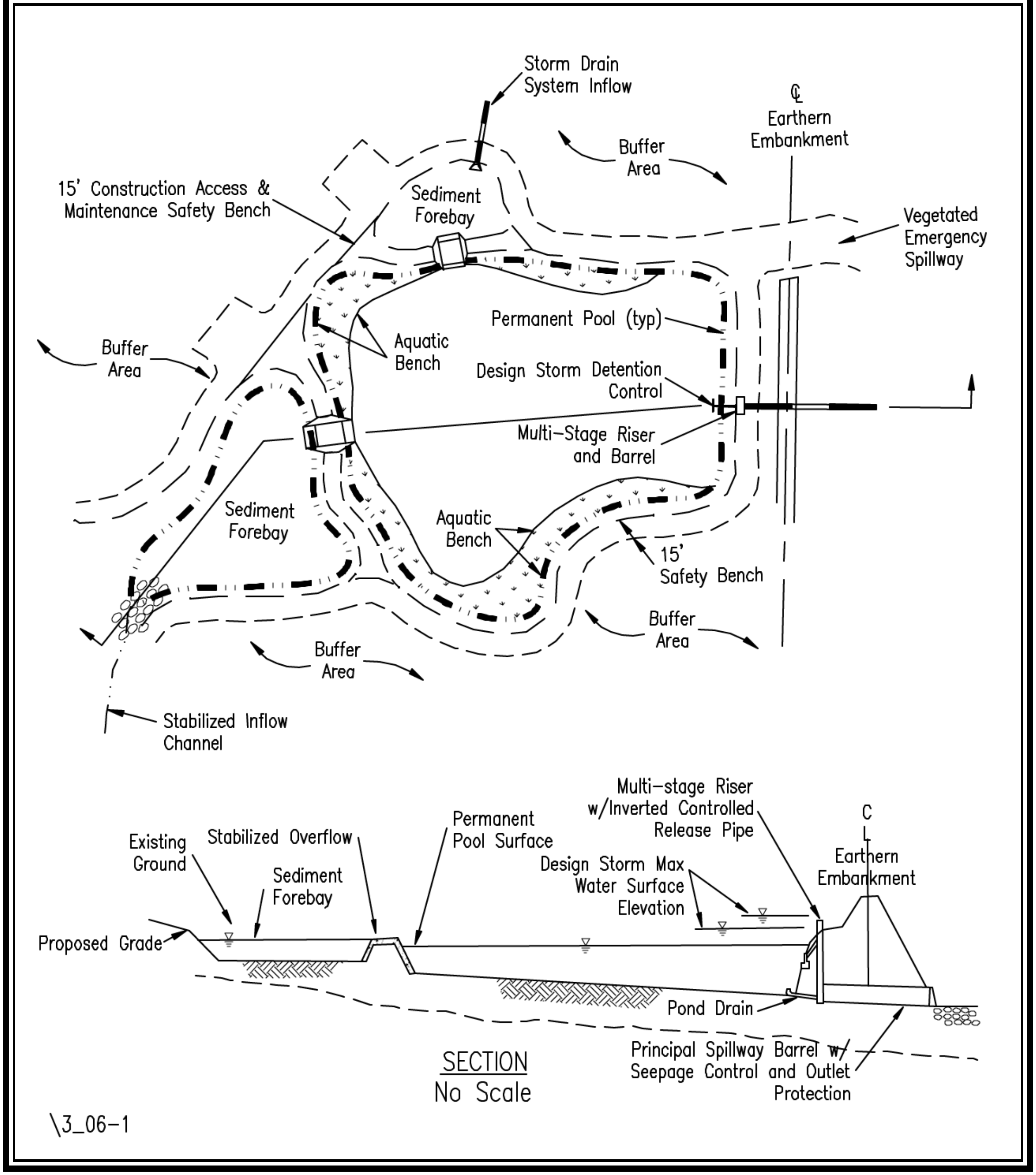

**TABLE 3.06 - 1**
***Pollutant Removal Efficiencies for Retention Basins***

| Type | Sizing Rule | Target Phosphorus Removal Efficiency | Impervious Cover |
|---|---|---|---|
| Retention Basin I | 3.0 x WQ Volume | 40% | 22-37% |
| Retention Basin II | 4.0 x WQ Volume | 50% | 38-66% |
| Retention Basin III | 4.0 x WQ Volume with Aquatic Bench | 65% | 67-100% |

Flood Control

Retention basins which provide flood control are designed with "dry" storage above the permanent pool. This dry storage works in concert with a riser or control structure to reduce the peak rate of runoff from a drainage area. Typically, the design storms selected for flood control (i.e., 2-year, 10-year frequency, etc.) are specified by state and local ordinances, or are based on specific watershed conditions. In either case, the required volume to be stored above the permanent pool can be readily determined using the hydrologic methods discussed in **Chapter 4**. Similarly, a control or spillway structure can be designed using the engineering calculation procedures presented in **Chapter 5**.

Channel Erosion Control

The storage volume above the permanent pool can also be used to control or reduce channel erosion. Channel erosion protection can be accomplished by reducing the peak rate of discharge, similar to flood control, or by controlling the time over which the peak volume of discharge is released (extended detention), similar to water quality enhancement. **Chapter 5-11** provides a discussion on the design criteria for channel erosion control.

## Conditions Where Practice Applies

Drainage Area

**A contributing watershed of at least 10 acres and/or a good source of baseflow should be present for a retention basin to be feasible**. Even with 10 acres of contributing watershed, the permanent pool may be susceptible to dry weather drawdowns due to infiltration and evaporation.

(Refer to **Chapter 5, Appendix 5C** for water balance calculation procedures.) Dry weather stagnation may result in aesthetic and odor problems for adjacent property owners. Therefore, for residential or high visibility applications, a minimum of 15 to 20 acres of contributing watershed may be more appropriate. Infiltration basins, trenches or extended-detention basins are more suitable for smaller sites.

A retention basin is recommended for use as a regional or watershed-wide stormwater management facility since its cost per acre treated is inversely proportional to the watershed size. Studies confirm that the most cost-effective application of a retention basin is on larger, more intensely developed sites (Schueler, et. al., 1985).

***Note that excavated retention basins in areas of high groundwater, such as in Tidewater, Virginia, may be feasible with very small drainage areas. The groundwater elevation should be carefully monitored, however, to verify the design permanent pool elevation.***

<u>Development Conditions</u>

Retention basins have the potential for removing high levels of soluble and particulate pollutants which makes them suitable for most types of development. They are appropriate for both high- and low- visibility sites. However, for high-visibility sites, care must be taken to avoid the aesthetic problems associated with stagnation or excessive infiltration of the permanent pool. Maintenance of the permanent pool is not necessarily critical to the retention basin's ability to remove pollutants, but maintenance **is critical** to ensure the BMP's acceptance by adjacent landowners. If adequate space is available, retention basins may also be used for both high and low density residential or commercial developments.

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A minimum 20-foot wide vegetated buffer should be provided around a retention basin to help filter out pollutants before they enter the basin. This requirement results in the need for more land, especially for those basins that may already be oversized to enhance their pollutant removal capabilities. It is for this reason that the use of large retention basins may not be a feasible option in developing watersheds where land is at a premium. This strengthens the argument for a regional or watershed approach to stormwater management. A regional retention or extended-detention basin is not only more cost-effective, it is also more likely to be installed on land that is not suitable for development. (It should be noted, however, that the environmental impacts and appropriate permits must still be considered for such an application.)

## Planning Considerations

The success of a retention basin is dependent on the designer's ability to identify any site or downstream conditions that may affect the design and function of the basin. Above all, the facility should be compatible with both upstream and downstream stormwater systems, thus promoting a *watershed approach* in providing stormwater management.

Site Conditions

Existing site conditions should be considered in the design and location of a retention basin. Features such as topography, wetlands, structures, utilities, property lines, easements, etc., may impose constraints on the location or construction of the basin. Local government land use and zoning ordinances may also designate certain requirements.

All retention basins should be a minimum of 20 feet from any structure or property line (as required by local ordinances), and 100 feet from any septic tank/drainfield. (The designer should be aware that an impoundment of water may elevate the local water table which could adversely effect drainfields and structures.) Retention basins should be a minimum of 50 feet from any steep slope (greater than 15%). Alternatively, a geotechnical report must address the potential impact of any retention basin that is to be constructed on or near such a slope.

Additional considerations are as follows:

1. **Soils –**

In the past, many designs were accepted based upon soils information compiled from available data, such as SCS soil surveys. While such a source may be appropriate for a pre-engineering feasibility study, final design and acceptance **should be based on an actual subsurface analysis and a permeability test**, accompanied by appropriate engineering recommenda- tions. The references listed at the end of this standard and at the end of **Minimum Standard 3.10, Infiltration Practices** provide more detailed information regarding the feasibility analysis of subsurface conditions for various soil types. Due to its complexity, this topic is not covered here. Note that the geotechnical study required for the embankment design (reference **Minimum Standard 3.01, Earthen Embankment**) will often provide adequate data to verify the soil's suitability for a retention basin.

The goal of a subsurface analysis is to determine if the soils are suitable for a retention basin. The textural character of the soil horizons and/or strata units within the subsoil profile should be identified to at least 3 feet below the facility bottom. This information is used to verify the infiltration rate or permeability of the soil. For a retention basin, water inflow (base flow and groundwater) must be greater than water losses (infiltration and evaporation). If the infiltration rate of the soil is too high, then a retention basin may not be an appropriate BMP.

**Permeable soils are not suited for retention basins**. The depth of the permanent pool can influence the rate at which water will infiltrate through the existing soil. The soil permeability may be such that the basin can support a shallow marsh or constructed wetland. However, as the depth of the permanent pool increases, the increased head or pressure on the soil may increase the infiltration rate. If necessary, a liner of clay, geosynthetic fabric, or other suitable material may be used in the basin (as specified by a geotechnical engineer). Refer to the design criteria for basin liners.

2. **Rock –**

A subsurface investigation should also identify the presence of rock or bedrock. Excavation of rock may be too expensive or difficult with conventional earth moving equipment, precluding the use of a basin. Blasting the rock for removal may be possible, but blasting may open seams or create cracks in the underlying rock, resulting in an unwanted drawdown of the permanent pool. Blasting of rock is not recommended unless a liner, as described above, is installed.

3. **Karst –**

In regions where Karst topography is prevalent, projects may require thorough soils investigations and specialized design and construction techniques. The presence of karst should be determined **during the planning phase of the project** since it may affect BMP selection, design, and cost.

4. **Existing Utilities–**

Most utility companies will not allow a permanent or temporary pool to be installed over their underground utility lines or right-of-ways. However, if such a site must be used, the designer should obtain permission from the utility company **before designing** the basin. The relocation of any existing utilities should be researched and the costs included in the overall basin cost estimate.

Environmental Impacts

1. **Wetlands –**

Large facilities and/or regional facilities naturally lend themselves to being placed in low lying, and usually environmentally sensitive, areas. Such locations often contain wetlands, shallow marshes, perennial streams, wildlife habitat, etc., and may be protected by state or federal laws. The owner or designer should investigate regional wetland maps and contact appropriate local, state, and federal agencies to verify the presence of wetlands, their protected status, and suitability for a retention basin at the location in question.

With careful planning, it may be possible to incorporate wetland mitigation into a retention basin design. This assumes that the functional value of the existing or impacted wetland can be identified and included, reconstructed, or mitigated for, in the basin. The Virginia Department of Environmental Quality should be contacted for more information regarding wetland mitigation.

2. **Downstream Impacts –**

A retention basin may have an adverse impact on downstream water quality by altering the biological oxygen demand (BOD), dissolved oxygen (DO), temperature, etc., of the water body. This is of special concern in cold water trout streams. The release depth of the control structure, overall pond depth, hydraulic residence time, and other design features can be manipulated to help meet the site specific needs of the downstream channel.

Urban detention and retention basin design should be coordinated with a watershed or regional plan for managing stormwater runoff, if available. In a localized situation, an individual basin can provide effective stream protection for the downstream property if no other areas contribute runoff in a detrimental way to that property. However, an uncontrolled increase in the number of impoundments within a watershed can severely alter natural flow conditions, causing combined flow peaks or increased flow duration. This can ultimately lead to downstream flooding and degradation.

3. **Upstream Impacts –**

The upstream channel must also be considered, especially when the retention basin is to be used to control downstream channel erosion. Erosive upstream flows will not only degrade the upstream channel, but will also significantly increase the maintenance requirements in the basin by depositing large amounts of sediment eroded from the channel bottom.

Water Quality Enhancement

A retention basin is typically selected for its water quality enhancement abilities and/or aesthetic value. The flexibility of providing for additional control components (channel erosion control, flood control, habitat, etc.) increases their value. The permanent pool of a retention basin serves to enhance the quality of the stormwater within it. Studies show that providing a larger permanent pool, and/or adding modifications such as an aquatic bench, sediment forebay, etc., will provide greater and more consistent pollutant removal benefits (refer to the **Design Criteria** section in this standard). Currently, no credit is given for any additional pollutant removal efficiency that may occur with an extended-detention volume stacked on top of the permanent pool of a retention basin. However, significant improvements in channel erosion control have been reported using extended-detention for the 1-year frequency design storm (Galli, MWCOG, 1992). Refer to **Minimum Standard 3.07, Extended Detention Basins**.

A concern in specifying a retention basin is how much land it will occupy. The size of the permanent pool will be based on the desired pollutant removal efficiency. The “dry” storage volume above the permanent pool will be sized for downstream channel erosion and/or flood control. The size of these two components together will determine the size of the basin.

*Preliminary sizing estimates for the permanent pool and "dry" storage volume are recommended during the planning stages to evaluate the feasibility of using a retention basin.*

If a retention basin is used to remove pollutants, the water quality within the basin will be lowered, thus possibly reducing its desirability for water supply, recreation, and aesthetic purposes. Therefore, the engineer should be aware of the site's specific runoff components and understand their possible effects on the quality of the stored water. Runoff from highways and streets can be expected to carry significant concentrations of heavy metals such as lead, zinc, and copper. These and other heavy metals may accumulate in the bottom of a facility, creating a potential health and environmental hazard. If a basin is in a watershed where a significant portion of the runoff is from highways, streets or parking areas, then access to the facility should be limited and warning signs should be posted. Proper disposal of the bottom sediments from these basins may require that they be hauled to an approved facility.

Further, retention basins in residential areas are subject to nutrients from lawn fertilizers and other urban sources. Excess nutrients can lead to algae and other undesirable vegetation which can diminish the aesthetic and recreational value of the basin.

Flooding and Channel Erosion Control

Flood control and downstream channel erosion are managed by providing additional storage volume, referred to as dry storage, above the permanent pool, and properly sizing a discharge opening in the riser structure.

When a retention basin is designed for channel erosion control and/or flood control, but **not** water quality enhancement, the permanent pool volume should be sized to address maintenance, aesthetic, and feasibility concerns (adequate drainage area, etc.).

Sediment Control

A stormwater retention basin may initially serve as a sediment control basin during the project's construction. A sediment basin is designed for the maximum drainage area expected to contribute to the basin during the construction process, while a permanent stormwater basin is designed based on post-developed land use conditions. When designing a facility to do both, the basin should be sized using the most stringent criteria, sediment control or stormwater management, which will result in the largest storage volume. The design elevations should be set with final clean out and conversion in mind. The bottom elevation of the permanent SWM basin should be lower than the design bottom of the temporary E&S basin. This allows for the establishment of a solid permanent bottom after sediment is removed from the facility.

The riser and barrel hydraulics and materials should be designed as the permanent stormwater control structure. However, the permanent riser may be temporarily modified to provide a sediment basin with wet and dry storage as required by the Virginia Erosion and Sediment Control Handbook, (VESCH), 1992 edition.

Safety

Basins that are readily accessible to populated areas should include all possible safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter should be avoided and dangerous outlet structures should be protected by enclosures. Warning signs for deep water and potential health risks should be used wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks or paths. A notice should be posted warning residents of potential waterborne disease that may be contracted by swimming or diving in these facilities.

If the basin's surface area exceeds 20,000 square feet, an aquatic bench should be provided. (Refer to the **Design Criteria for Aquatic Bench**.)

A fence is **required** at or above the maximum water surface elevation **when a basin slope is a vertical wall**. Local governments and homeowner associations may also require appropriate fencing without regard for the steepness of the basin side slopes.

Maintenance

Retention basins have shown an ability to function as designed for long periods without routine maintenance. However, some maintenance is essential to protect the aesthetic and wildlife properties of these facilities.

Vehicular access to the permanent pool area and release structure must be provided to allow for long-term maintenance operations (such as sediment removal) and repairs, as needed. The incorporation of a *sediment forebay* at the inflow points into the basin will help to localize disturbance during sediment removal operations. An onsite area designated for sediment dewatering and disposal should also be included in the design. Care must be taken in the disposal of sediment that may contain an accumulation of heavy metals. **Sediment testing is recommended prior to sediment removal to assure proper disposal**.

A sign should be posted near the basin that clearly identifies the person or organization responsible for basin maintenance. Allowing participation by adjacent landowners or visitors is very helpful, especially if the facility serves as a recreational facility. Maintenance needs that are observed and addressed early will help to lower the overall maintenance costs. Routine maintenance inspections, however, should be conducted by authorized personnel. In all cases, access easements should be provided to facilitate inspection and maintenance operation.

## Design Criteria

This section provides recommendations and minimum criteria for the design of stormwater retention basins intended to comply with the Virginia Stormwater Management program. It is the designer's responsibility to decide which aspects of the program apply to the particular facility being designed and if any additional design elements are required. The designer should also consider the long-term functioning of the facility in the selection of materials for the structural components.

### Hydrology and Hydraulics

**Chapter 4**, **Hydrologic Methods** and **Chapter 5**, **Engineering Calculations** should be used to develop the pre- and post-developed hydrology for a basin's contributing watershed, to design and analyze the hydraulics of the riser and barrel system, and to design the emergency spillway.

The design of the riser and barrel system should take into account any additional storage provided above the permanent pool for peak discharge control. Generally, the 2-year storm should be used in *receiving channel adequacy* calculations and the 10-year storm should be used for *flood control* calculations. Alternative requirements such as 1-year extended detention for channel erosion control may be imposed by local ordinances.

The contributing drainage area should be a minimum of 10 acres with an adequate base flow. Fifteen to 20 acres is more appropriate to sustain a healthy permanent pool. Note that this requirement may preclude the use of the Modified Rational Method for the basin's design.

### Embankment

The design of the earthen embankment for a retention basin should comply with **Minimum Standard 3.01, Earthen Embankment**. The requirements for geotechnical analysis, seepage control, maximum slopes and freeboard are particularly appropriate.

### Principal Spillways

The design of the principal spillway and barrel system, anti-vortex device, and trash racks should comply with **Minimum Standard 3.02, Principal Spillway**.

### Emergency Spillway

An emergency spillway that complies with **Minimum Standard 3.03, Vegetated Emergency Spillway** should be provided when possible, or appropriate.

Sediment Basin Conversion

**When a proposed stormwater facility is used as a temporary sediment basin, the conversion to the permanent facility should be completed after final stabilization and approval from the appropriate erosion and sediment control authority.**

In most cases the design criteria for the temporary sediment basin will require more storage volume (combined wet and dry) than that of a stormwater basin. In such cases, the extra volume should be allocated to the component of the facility that would derive the greatest benefit from the increased storage. This will depend on the primary function of the facility (i.e., water quality enhancement, flood control, or channel erosion control).

If modifications to the riser structure are required as part of the conversion to a permanent stormwater facility, they should be designed so that a) *the structural integrity of the riser is not threatened*, and b) *large construction equipment is not needed within the basin*. Any heavy construction work required on the riser should be completed during its initial installation. It is **NOT** recommended to install a temporary riser structure in the sediment basin and then replace it with a permanent riser after final stabilization. This may affect the structural integrity of the existing embankment and barrel.

The following additional criteria should be considered for a conversion:

1. Final elevations and a complete description of any modifications to the riser structure's geometry should be shown in the approved plans.
2. The wet storage area must be dewatered following the methods outlined in the VESCH, 1992 edition.
3. Sediment and other debris should be removed to a contained spoil area. Regrading of the basin may be necessary to achieve the final design grades and to provide an adequate topsoil layer to promote final stabilization.
4. Final modifications to the riser structure should be carefully inspected for watertight connections and compliance with the approved plans.
5. Final landscaping and stabilization should be per the VESCH, 1992 edition, and **Minimum Standard 3.05, Landscaping** in this handbook.

Permanent Pool

When designing a permanent pool for water quality benefits, certain physical and hydraulic factors can be manipulated to achieve a desired *pollutant removal efficiency*. These factors, which also influence the downstream water quality, include the permanent pool's *volume*, *depth*, *geometry*, *hydraulic residence time*, and *release depth*.

1. **Volume –**

Increasing the *volume* of the permanent pool increases the *residence time*, resulting in an increase in the pollutant removal efficiency of the permanent pool. **Table 3.06-1** provides the target pollutant removal efficiencies associated with different sizing rules.

2. **Depth –**

The *depth* of the permanent pool will affect several features of a retention basin including a) *aquatic plant selection*, b) *fish and wildlife habitat selection*, and c) *the rate at which nutrients are cycled*. Retention basins and artificial marshes built too shallow will not support fish populations year round. Basins built too deep may stratify, creating anaerobic conditions that may result in the resolubilizing of pollutants that are normally bound in the sediment. The release of such pollutants back into the water column can seriously reduce the effectivenes of the BMP and may cause nuisance conditions.

The depth of a stormwater management basin should vary to include as much diversity as possible, with an average depth of 3 to 6 feet. Approximately 15% of the basin area should be less than 18 inches deep. (Schueler, 1987). This can be accomplished by using an aquatic bench along the perimeter of the permanent pool as shown in **Figure 3.06-2**. **Table 3.06-2** below provides recommended surface area - pool depth relationships.

**TABLE 3.06 - 2**

***Recommended Surface Area - Pool Depth Relationships for Retention Basins***

| **BMP** | **Pool Depth (*ft.*)** | **Surface Area (*as % of total BMP surface area*)** |
|---|---|---|
| Retention Basin | 0 - 1.5<br>1.5 - 2<br>2 - 6 | 15%<br>15%<br>70% |

*Source: Washington State D.O.E.*

3. **Geometry –**

The geometry of a stormwater basin and the associated drainage patterns are usually dictated by site topography and development conditions. However, the alignment of the incoming pipes should be manipulated relative to the release structure to the greatest extent possible to avoid *short-circuiting* of the incoming runoff. *Short-circuiting* is the condition where incoming runoff passes through the basin without displacing the old water. This can be avoided by maximizing the distance between the inlet and outlet structures. It can also be avoided by designing a *meandering* flow path through the basin, rather than a straight line flow path. In either case, a length-to-width ratio of 2:1 should be maintained. If site conditions prevent using the proper ratio, then baffles made from gabion baskets, earthen berms or other suitable materials may be used to lengthen the flow path (see **Figure 3.06-3**).

A retention basin should be multi-celled with at least two cells and preferably three. The first cell can be used as a sediment forebay to trap coarse sediments and reduce turbulence that may cause resuspension of sediments. This first cell should be easily accessible for maintenance purposes. The second (and third) cell provides for the further settling of pollutants and any biological processes.

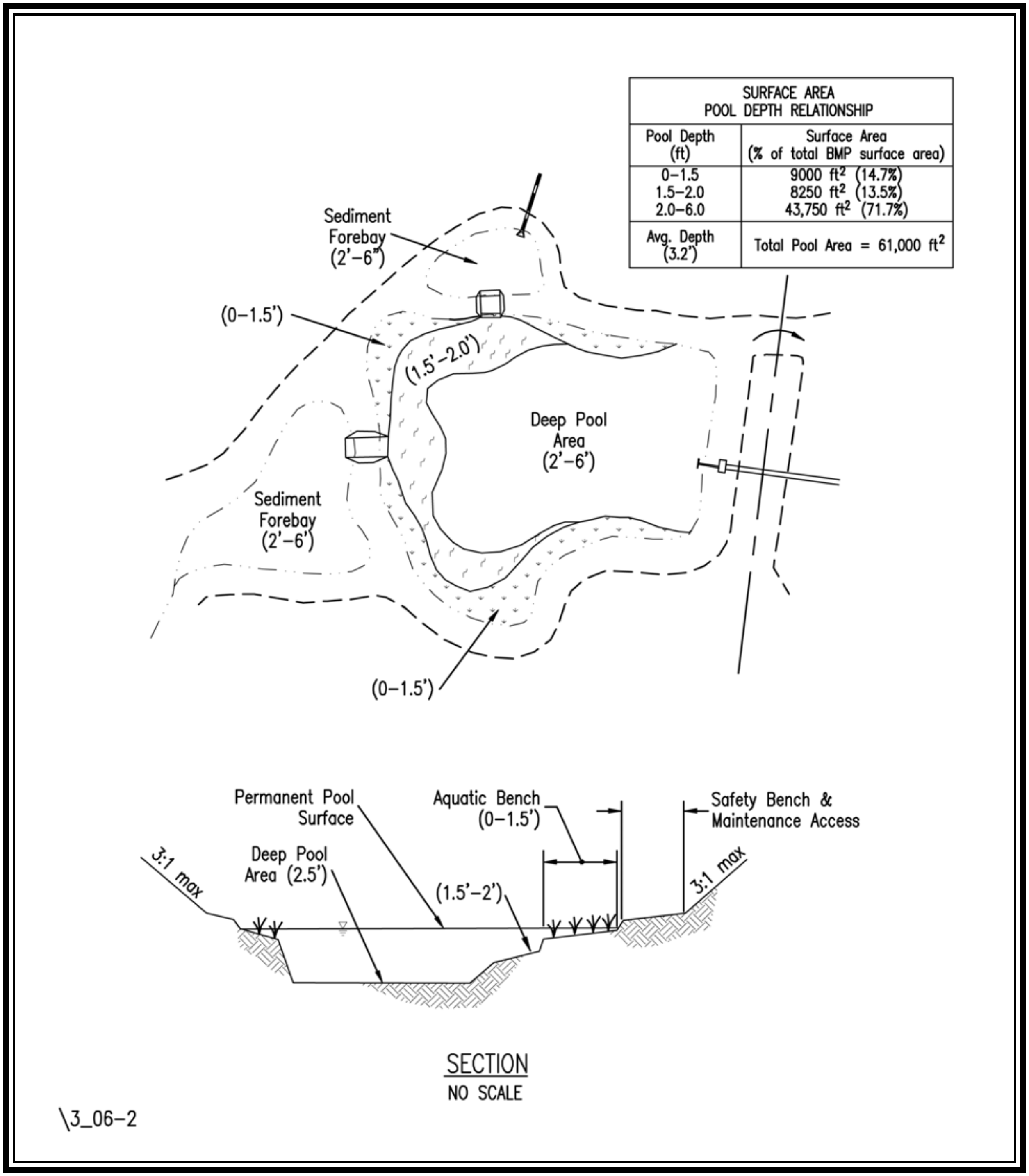
4. **Hydraulic Residence Time –**

*Hydraulic residence time* is the permanent pool volume divided by the average outflow discharge rate. The longer the residence time, the higher the pollutant removal efficiency (Driscoll, 1983, Kulzer, 1989). A retention basin used for channel erosion control and flood control will usually achieve higher pollutant removal rates. This is due to the increased residence time associated with the peak discharge control above the permanent pool. The hydraulic residence time would be a factor in the design of a retention basin with a permanent pool volume based on an impervious area which is relatively small when compared to the contributory drainage area. In this case, the total drainage area discharge will turn over, or replace, the volume of the "undersized" pool volume before it has achieved an adequate residence time. Optimal pollutant removal efficiency is generally associated with a *mean annual hydraulic residence* time of 14 to 30 days (Driscoll, 1988; Kulzer, 1989; Schueler, 1987).

5. **Release Depth –**

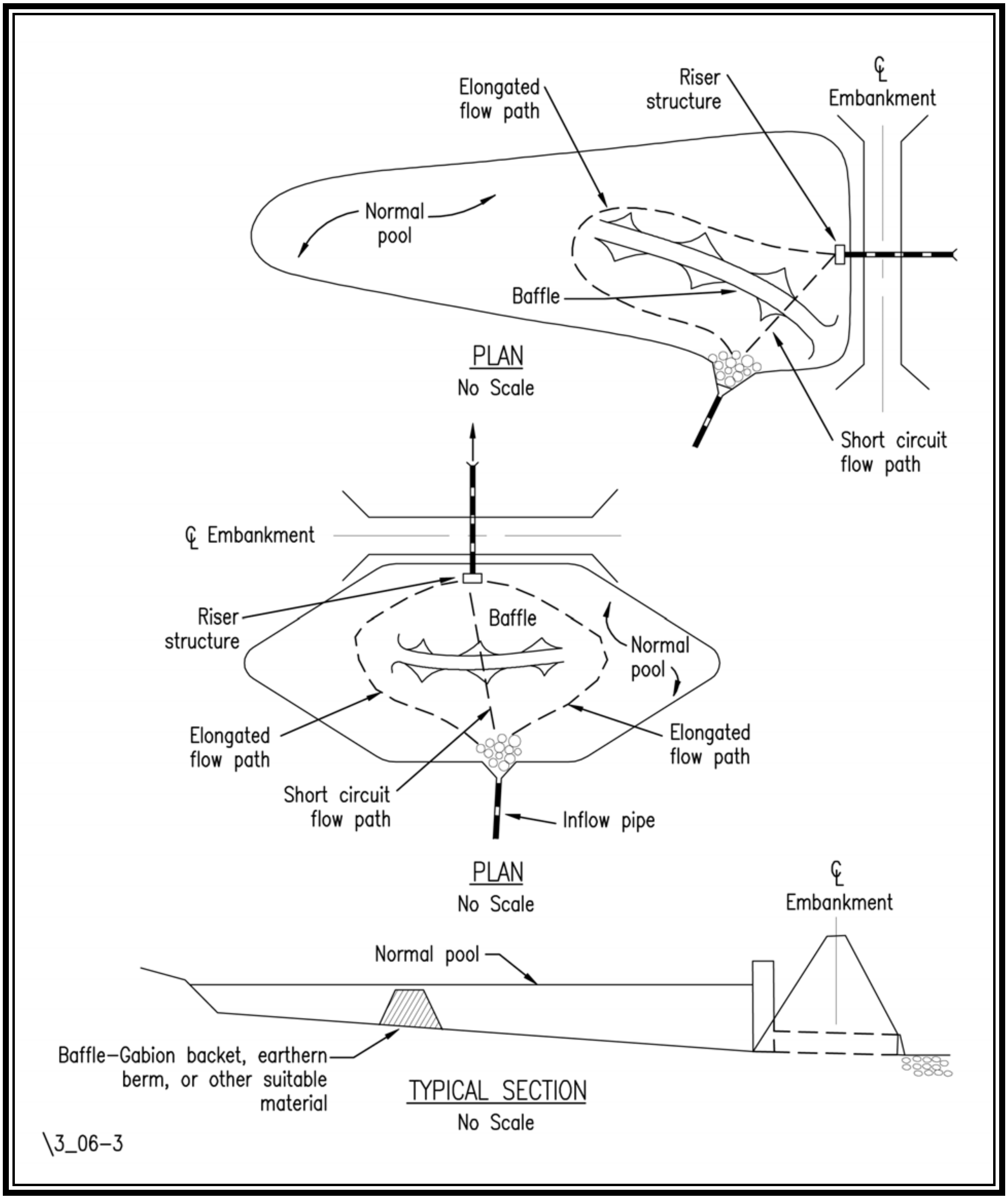
The best water quality in a retention basin's permanent pool is usually at or near the surface (Galli, 1988; Redfield, 1983). Under normal dry weather conditions, the concentrations of total dissolved solids, phosphorus, and nitrogen generally decrease in the upper portions of the water column due to physical settling and algal and biological assimilation (Galli, 1992). This suggests that <u>subsurface</u> releases have high levels of nutrients and suspended solids. In addition, deeper basins usually have very low levels of dissolved oxygen in the bottom portions of the water column.

**FIGURE 3.06 - 2**
***Varying Depth of Permanent Pool***




| SURFACE AREA POOL DEPTH RELATIONSHIP | |
|---|---|
| Pool Depth (ft) | Surface Area (% of total BMP surface area) |
| 0–1.5<br>1.5–2.0<br>2.0–6.0 | 9000 ft² (14.7%)<br>8250 ft² (13.5%)<br>43,750 ft² (71.7%) |
| Avg. Depth (3.2') | Total Pool Area = 61,000 ft² |

**FIGURE 3.06 - 3**
***Short-Circuiting***

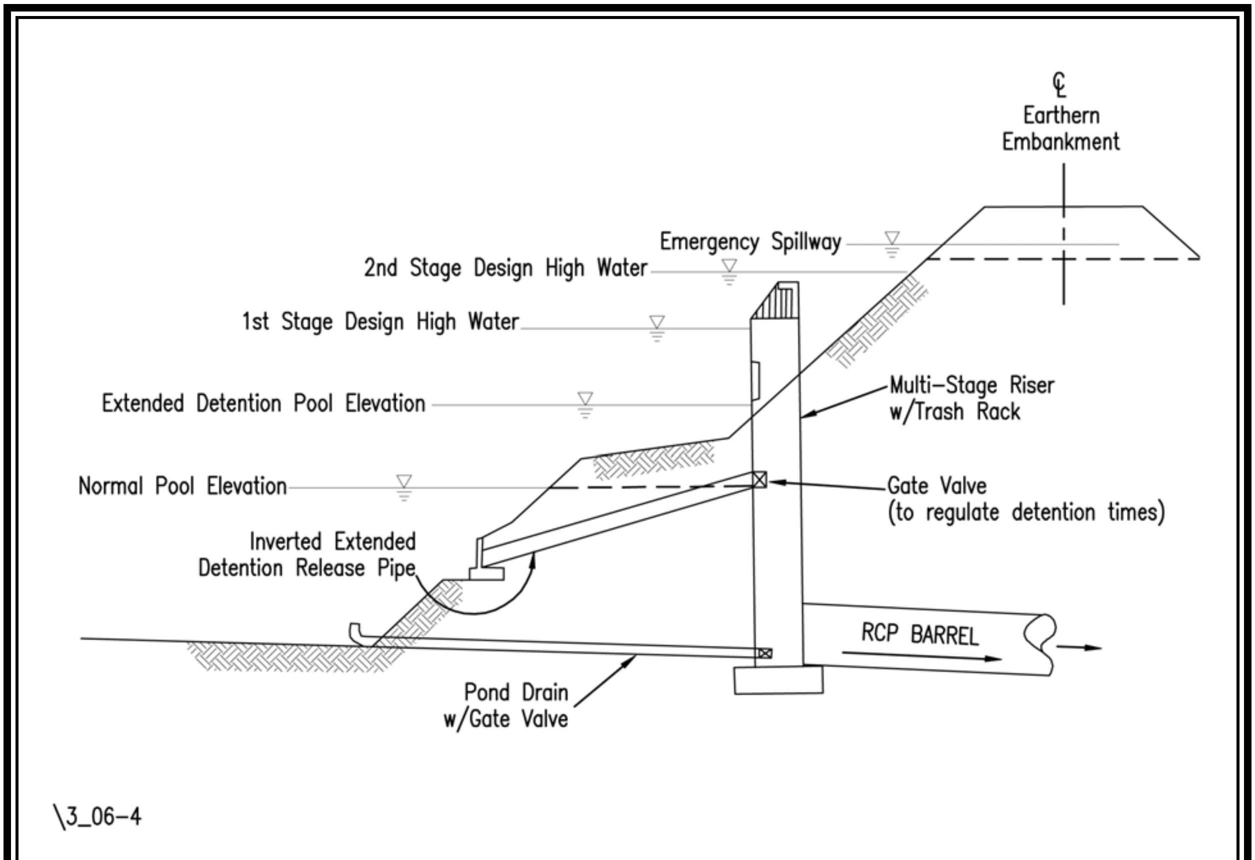


In contrast, the water at or near the surface of a retention basin is warmer because of solar heating of the basin and heated stormwater inflow. This resembles the cycling process of water in natural lakes and water bodies. However, the proximity of a retention basin to development (i.e., impervious surfaces) may lead to an excessive heat buildup from the incoming runoff during the warmer months. Therefore, a release depth of approximately 18 inches from the water surface is recommended (Galli, 1992) to avoid extremes in temperature, nutrient levels, and dissolved oxygen (see **Figure 3.06-4**).

It should be noted that inexpensive design modifications can be incorporated into the design of a retention facility to mitigate downstream impacts such as: a) *oversizing the barrel and adding surgestone or rip rap to the invert to help re-aerate the basin discharge* (Schueler, 1987), and b) *providing shade by planting (or saving) trees around the perimeter of the basin to help lower surface water temperature*.

If the receiving stream supports a trout population, the designer should contact the Department of Game and Inland Fisheries for additional measures to protect the downstream habitat.

**FIGURE 3.06 - 4**
***Typical Retention Basin Control Structure***



Aquatic Bench

The pollutant removal efficiency of a retention basin can be further enhanced by adding an *aquatic bench*. An aquatic bench is a 10 to 15 foot wide area that slopes from zero inches at the shoreline to between 12 and 18 inches deep in the basin (see **Figure 3.06-5**). This bench provides suitable conditions for a variety of aquatic plants and emergent vegetation. Specific landscaping requirements for an aquatic bench should be provided on the landscaping plan per **Minimum Standard 3.05, Landscaping**.

Most important, an aquatic bench augments the pollutant removal capabilities of a retention basin by providing an environment for aquatic vegetation and associated algae, bacteria and other microorganisms that reduce organic matter and nutrients (Schueler, 1987). In addition, aquatic bench vegetation provides an ideal habitat for wildlife, such as waterfowl and fish, and for predator insects that feed on mosquitoes and other nuisance insects.

An aquatic bench also serves to stabilize and protect the shoreline from erosion resulting from fluctuating water levels, and provides a safety feature by eliminating the presence of a steep submerged slope next to the shoreline.

The increase in pollutant removal efficiency associated with the establishment of an aquatic bench is **approximated** based on available information. Note that discharge monitoring may indicate much higher or lower values since many variables exist in any given stormwater basin design and the efficiencies are estimated.

Sediment Forebay

A *sediment forebay* will help to postpone overall basin maintenance by trapping incoming sediments at a specified location. The forebay should be situated and designed per **Minimum Standard 3.04, Sediment Forebays**. Usually, a sediment forebay is placed at the outfall of the incoming storm drain pipes or channels directed toward the basin and is situated to provide access for maintenance equipment.

A sediment forebay enhances the pollutant removal efficiency of a basin by trapping the incoming sediment load in one area, where it can be easily monitored and removed. The *target pollutant removal efficiency* of a retention basin, as listed in **Table 3.06-1**, is predicated on the use of sediment forebays at the inflow points to the basin.

Liner to Prevent Infiltration

A retention basin should have negligible infiltration through its bottom. Infiltration may impair the proper functioning of the basin and may contaminate groundwater. Where infiltration is anticipated, or in areas underlain by karst topography then a retention or detention facility should **not** be used unless an impervious liner is installed. When using a liner, the specifications provided in **Table**

**3.06-3** for clay liners and the following recommendations apply:

1. A clay liner should have a minimum thickness of 12 inches.

2. A layer of compacted topsoil (minimum thickness 6 to 12 inches) should be placed over the liner before seeding with an appropriate seed mixture (refer to the VESCH, 1992 edition.)

3. Other liners may be used provided the engineer can supply supporting documentation that the material will achieve the required performance.

In many cases, the fine particulates and suspended solids in the water column of a new retention basin will settle out and quickly clog the the pores of the bottom soil. However, a geotechnical analysis should address the potential for infiltration and, if needed, specify liner materials.

Safety

The side slopes of a retention basin should be no steeper than 3H:1V and should be stabilized with permanent vegetation. If the basin surface exceeds 20,000 square feet, an aquatic bench should be provided to serve as a safety feature. Fencing may also be required by local ordinance.

Access

A 10 to 12-foot-wide access road with a maximum grade of 12% should be provided to allow vehicular access to both the outlet structure area and at least one side of the basin. The road's surface material should be selected to support the anticipated frequency of use and the anticipated vehicular load without excessive erosion or damage.

**TABLE 3.06 - 3**
***Clay Liner Specifications***

| Property | Test Method (or equal) | Unit | Specification |
|---|---|---|---|
| Permeability | ASTM D-2434 | *cm/sec* | $1 \times 10^{-6}$ |
| Plasticity Index of Clay | ASTM D-423 & D-424 | % | Not less than 15 |
| Liquid Limit of Clay | ASTM D-2216 | % | Not less than 30 |
| Clay Particles Passing | ASTM D-422 | % | Not less than 30 |
| Clay Compaction | ASTM D-2216 | % | 95% of Standard Proctor Density |

*Source: City of Austin, 1988*

Landscaping

A qualified individual should prepare the landscape plan for a retention basin. Appropriate *shoreline fringe*, *riparian fringe* and *floodplain terrace vegetation* must be selected to correspond with the expected frequency and duration of inundation. Selection and installation guidelines should be per **Minimum Standard 3.05, Landscaping**.

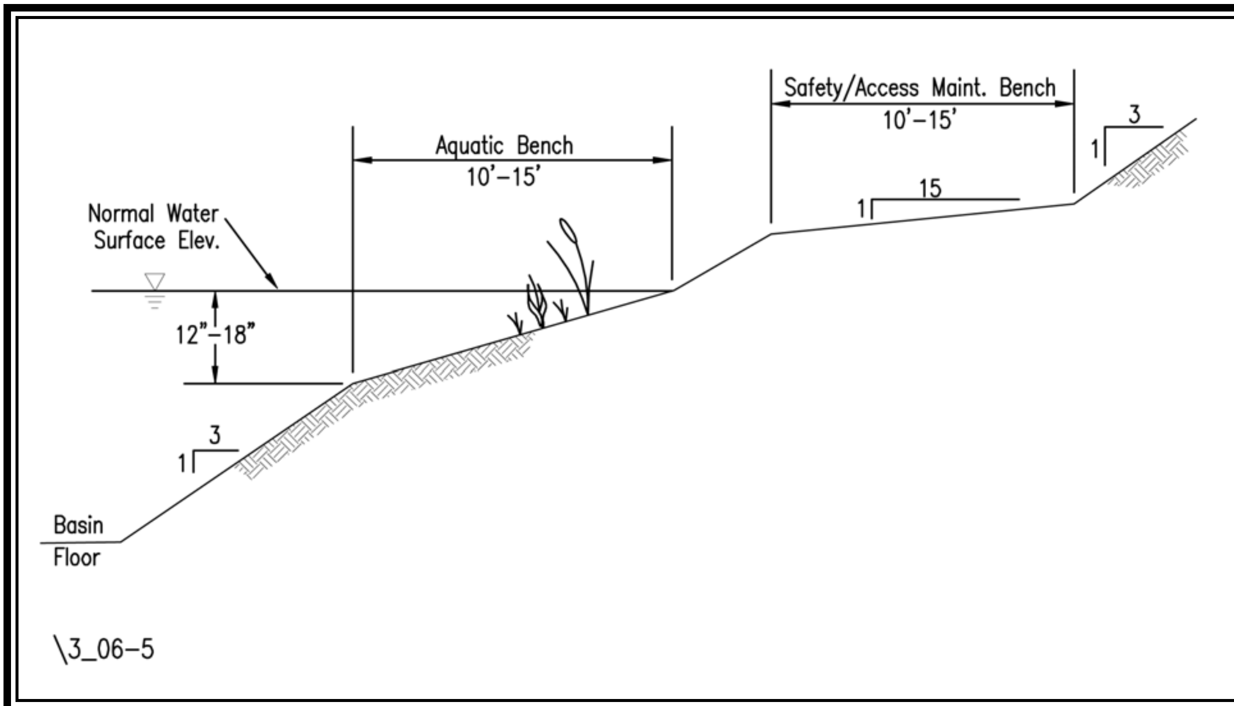
Vegetation should be planted in soil that is appropriate for the plants selected. Soil tests showing the adequacy of the soil or a soil enhancement plan should be submitted with the overall basin design.

The soil substrate must be soft enough to permit easy installation of the plants. If the basin soil has been compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked before planting. If soil is imported, it should be laid at least 6 inches deep to provide sufficient depth for plant rooting to occur.

Buffer Zones

A vegetated buffer strip should be maintained beside the basin. The strip should be a minimum of 20 feet wide, as measured from the maximum water surface elevation. Refer to **Minimum Standard 3.05, Landscaping**.

**FIGURE 3.06 - 5**
***Typical Retention Basin Aquatic Bench - Section***



## Construction Specifications

The construction specifications for stormwater retention basins outlined below should be considered minimum guidelines. More stringent or additional specifications may be required based on individual site conditions.

Overall, widely accepted construction standards and specifications for embankment ponds and reservoirs, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed to build an impoundment.

Further guidance can be found in Chapter 17 of the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry and any other items that are apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local plan approving authority.

The following minimum standards contain guidance and construction specifications for various components of retention basins: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; and **3.05, Landscaping**.

## Maintenance and Inspections

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here. The engineer is responsible for determining if any additional items are necessary.

Inspecting and maintaining the structures and the impoundment area should be the responsibility of either the local government, a designated group such as a homeowner's association or an individual. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations.

Any standing water pumped during the maintenance operation must be disposed of per the VESCH, 1992 edition and any local requirements.

### General Maintenance

Maintenance and inspection guidelines found in the following minimum standards apply: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; and **3.05: Landscaping**.

Vegetation

The basin's side slopes, embankment and emergency spillway should be mowed at least twice a year to discourage woody growth. For aesthetic purposes, more frequent mowing may be necessary in residential areas

Specific plant communities may require different levels of maintenance. Upland and floodplain terrace areas, grown as meadows or forests, require very little maintenance, while aquatic or emergent vegetation may need periodic thinning or reinforcement plantings. Note that after the first growing season, it should be obvious if reinforcement plantings are needed. If they are, they should be installed at the onset of the second growing season after construction.

Research indicates that for most aquatic plants the uptake of pollutants is stored in the roots, not the stems and leaves (Lepp 1981). Therefore, aquatic plants should not require harvesting before winter plant die-back. There are still many unanswered questions about the long term pollutant storage capacity of plants. It is possible that aquatic and emergent plant maintenance recommendations may be presented in the future.

Debris and Litter Removal

Debris and litter will accumulate near the inflow points and around the outlet control structure. Such material should be removed periodically. Also, as the water level rises during storm events, floatables accumulate around the grate or trash rack of the control structure. If a flat horizontal trash rack is used, floating debris will become lodged on the trash rack, which will remain clogged until it is manually cleaned. A significant accumulation can clog the riser structure. The use of an angled trash rack is recommended to allow any accumulated debris to slide off as the water level drops.

Sediment Removal

Sediment deposition should be continually monitored in the basin. Removal of any accumulated sediment, in the sediment forebay or elsewhere, is extremely important. A significant accumulation of sediment impairs the pollutant removal capabilities of the basin by reducing the permanent pool volume. The deposited sediment also becomes prone to resuspension during heavy flow periods. Unless unusual conditions exist, accumulated sediment should be removed from the sediment forebay and possibly other deep areas within the permanent pool every 5 to 10 years. The use of a sediment forebay with access for heavy equipment will greatly simplify the removal process. **During maintenance procedures, ensure that any pumping of standing water or dewatering of dredged sediments complies with the VESCH, 1992 edition, and any local requirements**.

Owners, operators, and maintenance authorities should be aware that significant concentrations of heavy metals (e.g., lead, zinc and cadmium) and some organics, such as pesticides, may be expected to accumulate at the bottom of a retention basin. Testing of sediment, especially near points of inflow, should be conducted regularly and **before disposal** to establish the leaching potential and level of accumulation of hazardous materials. Disposal methods must comply with applicable state and local regulations (e.g., for special waste).

Inspections

A retention basin and its components should be inspected annually, at a minimum, to ensure that they operate in the manner originally intended. Items in need of repair should be addressed promptly and as specified in the comprehensive maintenance program. Detailed inspections by qualified person(s) should address the following areas/concerns:

- Dam settling, woody growth, and signs of piping
- Signs of seepage on the downstream face of the embankment
- Condition of grass cover on the embankment, basin floor and perimeter
- Riprap displacement or failure
- Principal and emergency spillway meet design plans for operation
- Outlet controls, debris racks and mechanical and electrical equipment
- Outlet channel conditions
- Inlet pipe conditions
- Safety features of the facility
- Access for maintenance equipment
- Sediment accumulation
- Debris and trash accumulation
- Erosion of the embankment or side slopes

## Design Procedures

1. Determine if the anticipated development conditions and drainage area are appropriate for a stormwater retention basin BMP.

   C Minimum drainage area of 10 acres and/or base flow

2. Determine if the soils (permeability, bedrock, Karst, embankment foundation, etc.) and topographic conditions (slopes, existing utilities, environmental restrictions) are appropriate for a stormwater retention basin BMP.

3. Determine any additional stormwater management requirements (channel erosion, flooding) for the project.

4. Locate the stormwater retention basin on the site.

5. Determine the hydrology and peak discharges of the contributory drainage area for each of the required design storms (**Chapter 4, Hydrologic Methods**).

6. Calculate the permanent pool volume and approximate storage volume requirements (**Chapter 5, Engineering Calculations**).

7. Design the embankment (**Min. Std. 3.01**), principal spillway (**Min. Std. 3.02**), emergency spillway (**Min. Std. 3.03**), sediment forebay (**Min. Std. 3.04**), landscaping plan (**Min. Std. 3.05**), and the permanent pool and other components of a stormwater retention basin BMP (**Min. Std. 3.06**) using **Chapter 5, Engineering Calculations**, and the Minimum Standards listed.

   - permanent pool depth
   - Permanent pool geometry
   - release depth
   - aquatic bench
   - pond drain

8. Design final grading of basin.

   - landscape plan
   - 20-foot buffer area
   - safety (3:1 slopes with bench)
   - access

9. Establish specifications for sediment control and sediment basin conversion (if required).

10. Establish construction sequence and construction specifications.

11. Establish maintenance and inspection requirements.

## Checklists

Refer to **Appendix-3A** for **Design and Plan Review**, **Construction Inspection**, and **Operation and Maintenance** Checklists.

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Retention basin with small island.

Retention basin in ultra-urban setting (under construction).

# Retention Basin

Retention basin – Note flat slopes with “rough” edge and aquatic bench provided as safety and pollutant removal features.

# Retention Basin

*MINIMUM STANDARD 3.07*

# EXTENDED-DETENTION BASIN
# &
# *ENHANCED* EXTENDED-DETENTION BASIN

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.07

# EXTENDED-DETENTION BASIN & *ENHANCED* EXTENDED-DETENTION BASIN

### Definition

An extended-detention basin is an impoundment that temporarily stores runoff for a specified period and discharges it through a hydraulic outlet structure to a downstream conveyance system. An extended-detention basin is usually dry during non-rainfall periods.

### Purpose

An extended-detention basin can be designed to provide for one, or all, of the following: a) *water quality enhancement*, b) *downstream flood control*, and c) *channel erosion control*.

Water Quality Enhancement

An **extended-detention basin** improves the quality of stormwater runoff through gravitational settling. However, due to frequent high inflow velocities, settled pollutants often get resuspended.

An ***enhanced*** **extended-detention basin** has a higher efficiency than an extended-detention basin because it incorporates a shallow marsh in its bottom. The shallow marsh provides additional pollutant removal through *wetland plant uptake*, *absorption*, *physical filtration*, and *decomposition*. The shallow marsh vegetation also helps to reduce the resuspension of settled pollutants by trapping them.

The target pollutant removal efficiencies for both extended-detention and *enhanced* extended-detention basins are presented in **Table 3.07-1**. The target pollutant removal efficiencies are based on certain design criteria associated with the physical characteristics of the basin, and shallow marsh, when used.

**FIGURE 3.07 - 1a**
*Extended-Detention Basin - Plan*

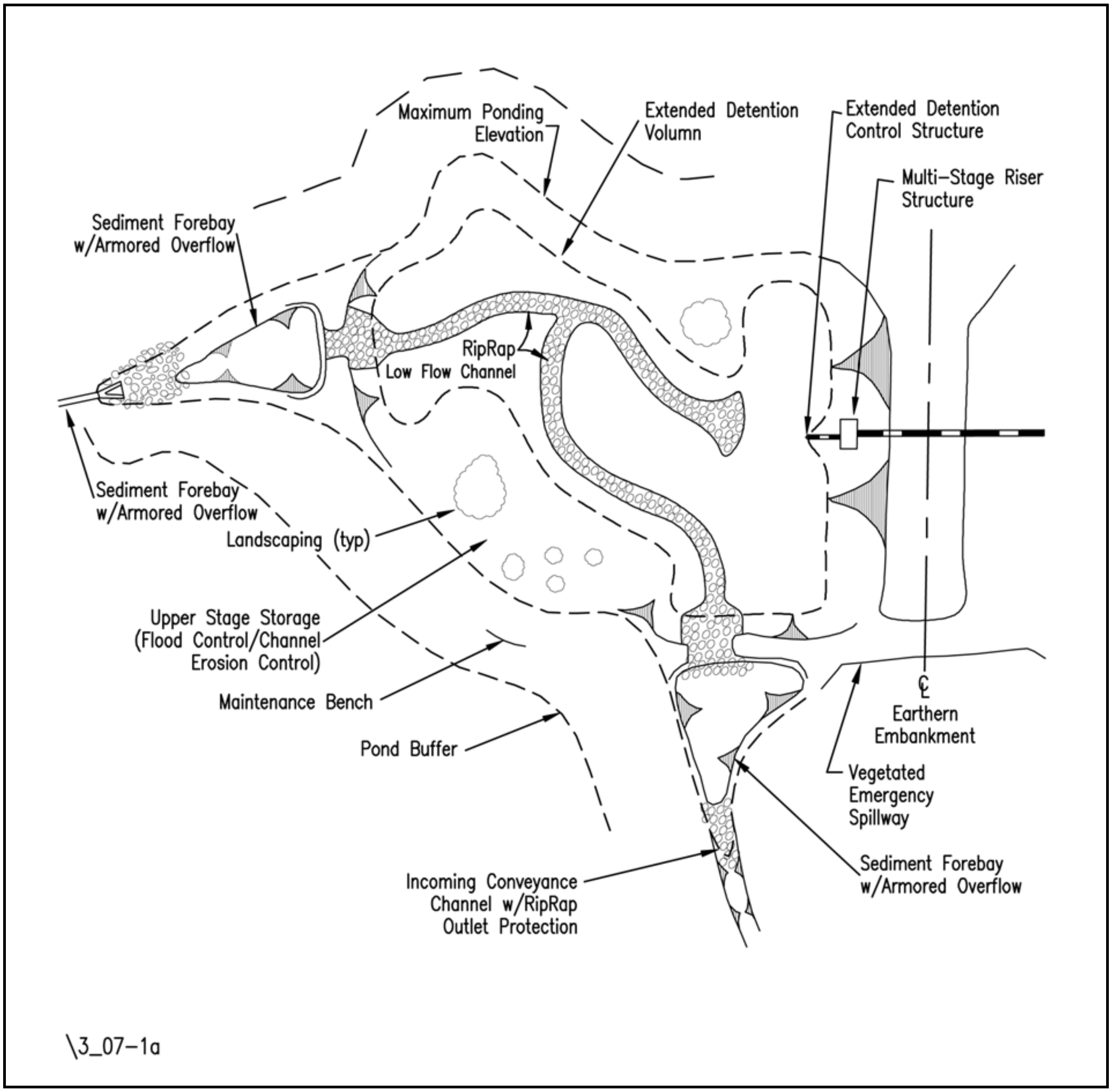
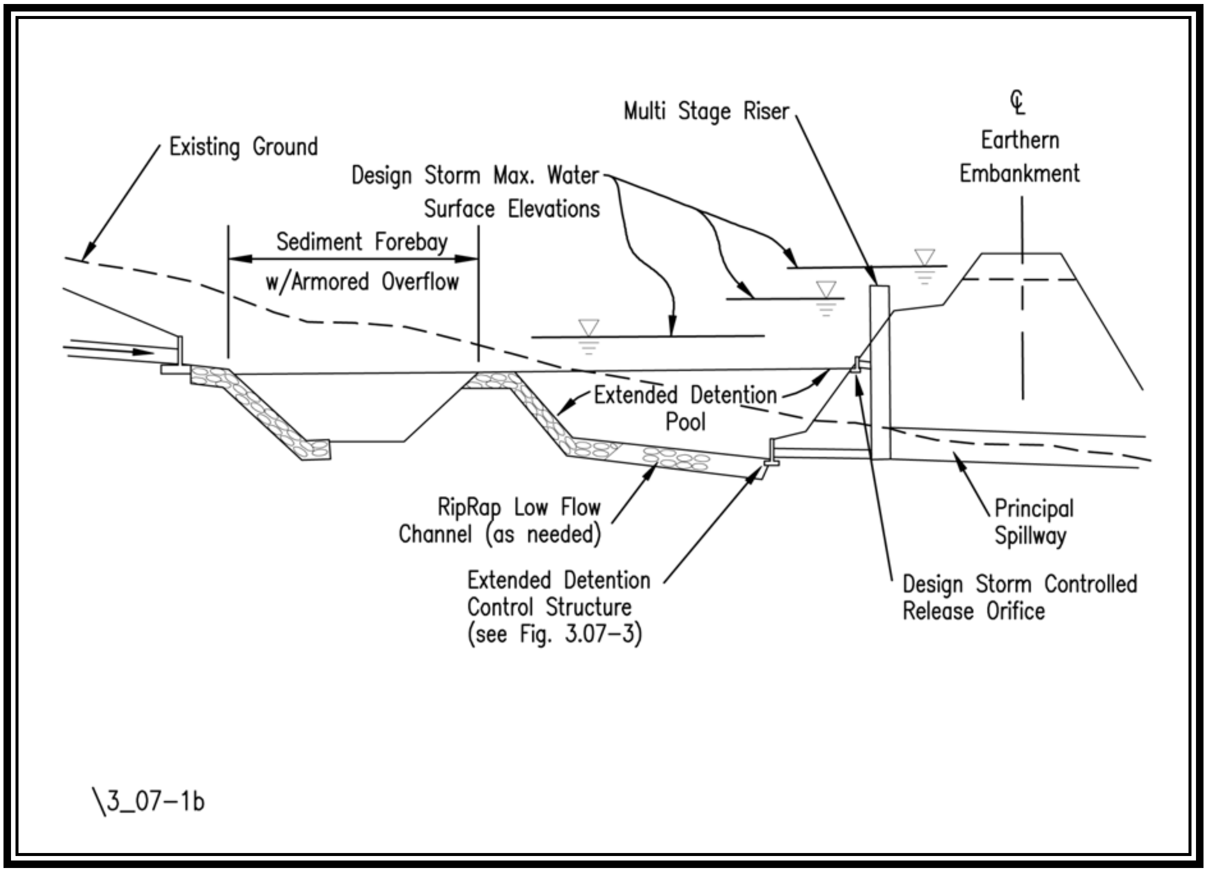


**FIGURE 3.07-1b**
***Extended-Detention Basin - Section***

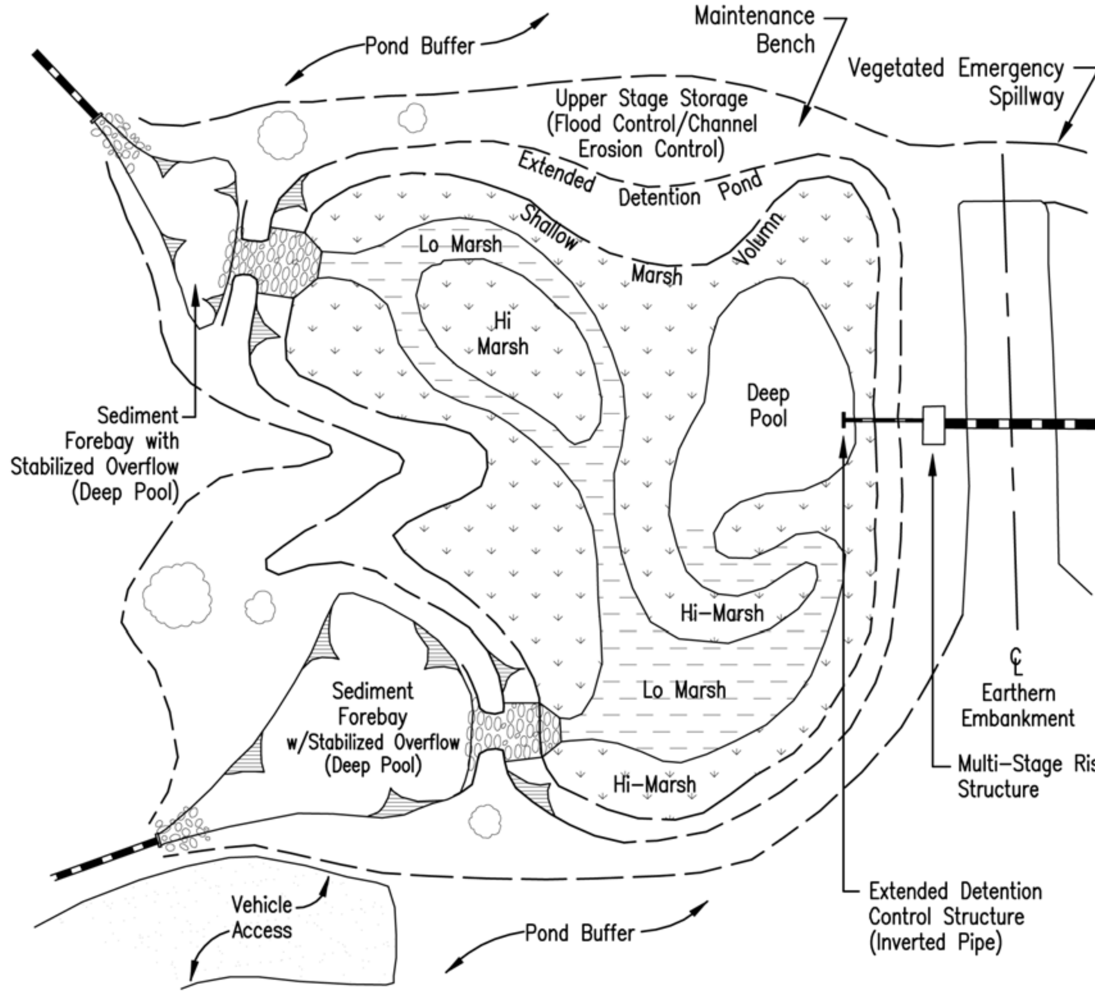



Flood Control

Extended-detention basins can be designed for flood control by providing additional storage above the extended-detention volume, and by reducing the peak rate of runoff from the drainage area. The design storms chosen for flood control are usually specified by ordinance, or are based on specific watershed conditions. By managing multiple storms, such as the 2- and 10-year storms, adequate flood control may be provided for a broad range of storm events.

The additional volume required for storage above the extended-detention volume can be readily determined using the hydrologic methods discussed in **Chapter 4, Hydrologic Methods**. Once this volume is known, a control or spillway structure can be designed and the reservoir routing and channel capacity design techniques discussed in **Chapter 5, Engineering Calculations**.

**FIGURE 3.07 - 2a**
***Enhanced Extended-Detention Basin - Plan***




| Depth Zone | % of Surface Areas |
|---|---|
| Deep Pool | 20% |
| Lo Marsh | 35% |
| Hi Marsh | 45% |

\3_07–2a

**FIGURE 3.07 - 2b**
***Enhanced Extended-Detention Basin - Section***

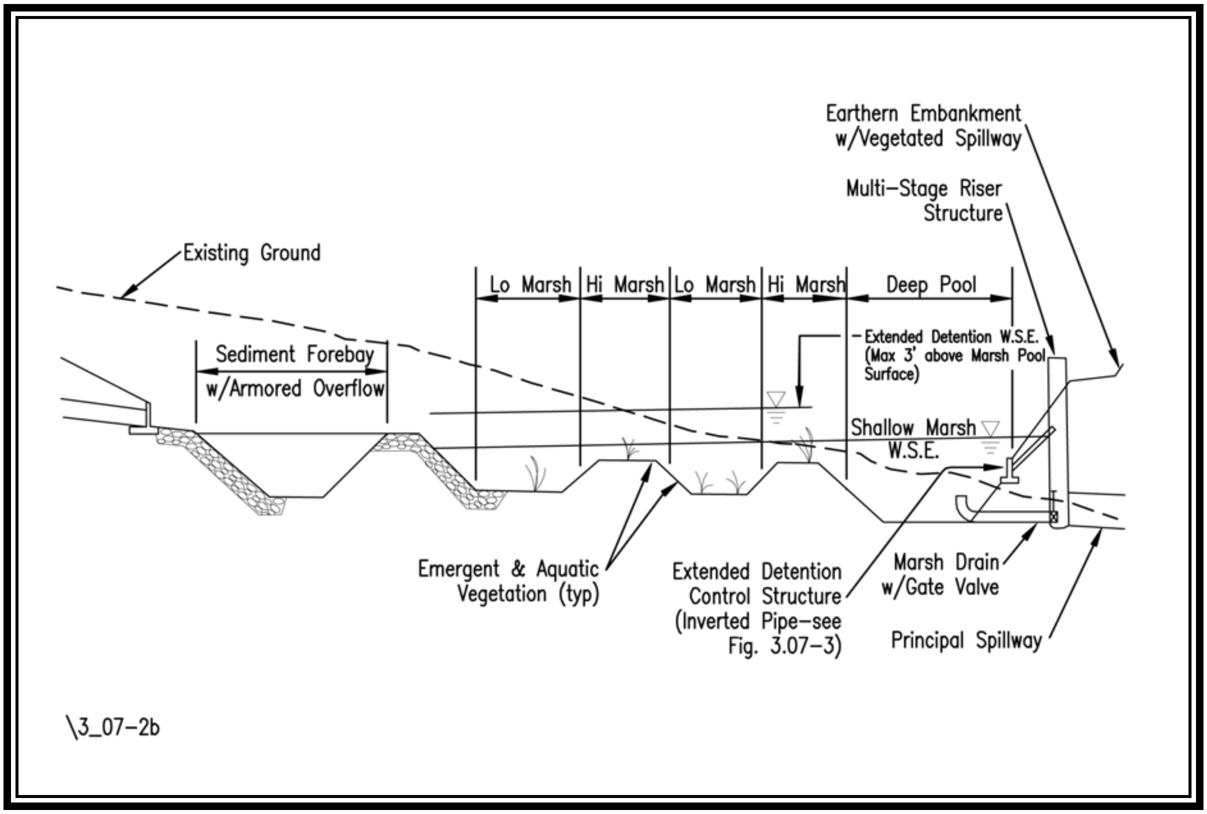



**TABLE 3.07 - 1**
***Pollutant Removal Efficiencies for***
***Extended-Detention & Enhanced Extended-Detention Basins***

| Type | Target Phosphorus Removal Efficiency | Impervious Cover |
|---|---|---|
| Extended-detention (30 *hr*. Drawdown of 2 × WQ Volume) | 35% | 22 - 37% |
| *Enhanced* extended-detention (30-*hr*. Drawdown of 1 × WQ Volume, and 1 × WQ Volume Shallow Marsh) | 50% | 38 - 66% |

Channel Erosion Control

The objective in controlling channel erosion is to reduce the rate of discharge from a designated frequency storm to below the critical velocity of the downstream channel. The critical velocity of a channel is the velocity that, when exceeded, causes the channel bed or banks to erode. The Virginia Erosion and Sediment Control Handbook, 1992 edition, provides the theoretical critical velocities for various natural channel linings. This critical velocity approach, however, does not consider the frequency or the duration of the critical velocity flow. An increase in impervious cover will increase the frequency of occurance of the "pre-developed" design storm discharge by raising the rainfall to runoff response characteristics of the drainage area. A detention basin will increase the duration of the "pre-developed" design storm discharge by releasing the runoff over time. (A detention basin lowers the peak by spreading it out over a longer period of time.) An extended-detention basin, on the other hand, reduces the discharge based on an extended period of time rather than a peak rate of discharge. Extended-detention of a specific design storm will typically result in lower rates of discharge than the "pre-developed" rate (or critical velocity), thereby compensating for the effects of increased frequency and duration.

The selection of an design storm and a extended-detention period is not a scientific process and is currently determined to be the runoff from the 1-year frequency storm, detained and released over a 24 hour period. Studies show a significant reduction in stream channel erosion below extended-detention facilities designed to this criteria (Galli MWCOG, 1992). Extended-detention of the 1-year storm lowers the discharge velocities from a broad range of storm frequencies to non-erosive levels.

## Conditions Where Practice Applies

Drainage Area

The **minimum** contributing drainage area for an extended-detention basin varies with the required extended-detention volume and draw down period and the resulting orifice size. The orifice configuration for small drainage areas should be selected carefully since small openings (less than 3 inches) are prone to clogging. Several different configurations for effective trash, debris, and sediment control are presented in **Figure 3.07-3**. The engineer is free to choose any of these, or to select from other innovative designs.

The **maximum** drainage area served by an extended-detention basin will vary from watershed to watershed. Drainage areas above 50 to 75 acres may require provisions for *base flow*. (Refer to **Design Criteria**). Care should be taken when sizing the water quality orifice if base flow is present.

An undersized orifice may create an undersized permanent pool within the extended-detention volume, leaving inadequate volume above it to provide the required extended-detention. An oversized orifice will result in little extended-detention of the water quality volume.

Development Conditions

Lacking a permanent pool of water, a detention facility is rarely considered aesthetically pleasing. It is, therefore, recommended for *low-visibility* sites. In certain situations, an extended-detention basin may be used on a *high-visibility* site, but the designer must be careful to avoid stagnation or excessive infiltration of the shallow marsh. Maintenance of the basin's shallow marsh is not necessarily critical to its ability to remove pollution, but maintenance **is critical** to ensure the BMP's acceptance by adjacent landowners.

Extended-detention basins can be used for low- to medium-density residential or commercial projects, as classified by their impervious cover. (see **Table 3.07-1**). Along with the storage and shallow marsh volumes required in the basin, a minimum 20-foot vegetated buffer should also be provided. This requirement results in the need for more land. It is for this reason that the use of extended-detention basins may not be the best choice of water quality BMP in developing watersheds where land is at a premium. This strengthens the argument for a regional or watershed approach to stormwater management. A regional extended-detention basin is not only more cost-effective, but is also more likely to be installed on land that is not suitable for development. (It should be noted, however,that the environmental impacts and appropriate permits must still be considered for such an application.)

**FIGURE 3.07 - 3a**

***Trash and Debris Rack Configurations for Extended-Detention Control Structures***

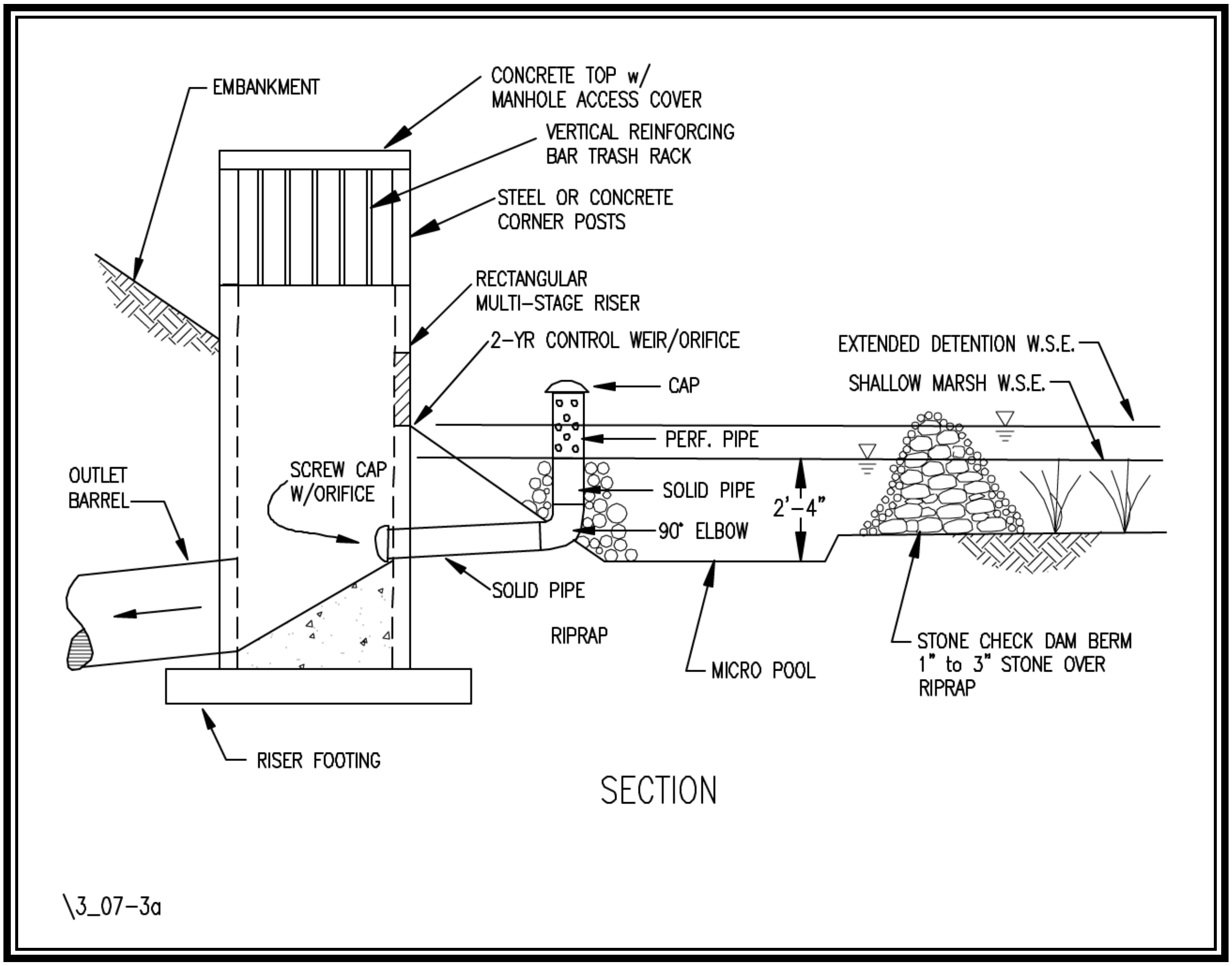


**FIGURE 3.07 - 3b**
***Trash and Debris Rack Configurations for Extended-Detention Control Structures***

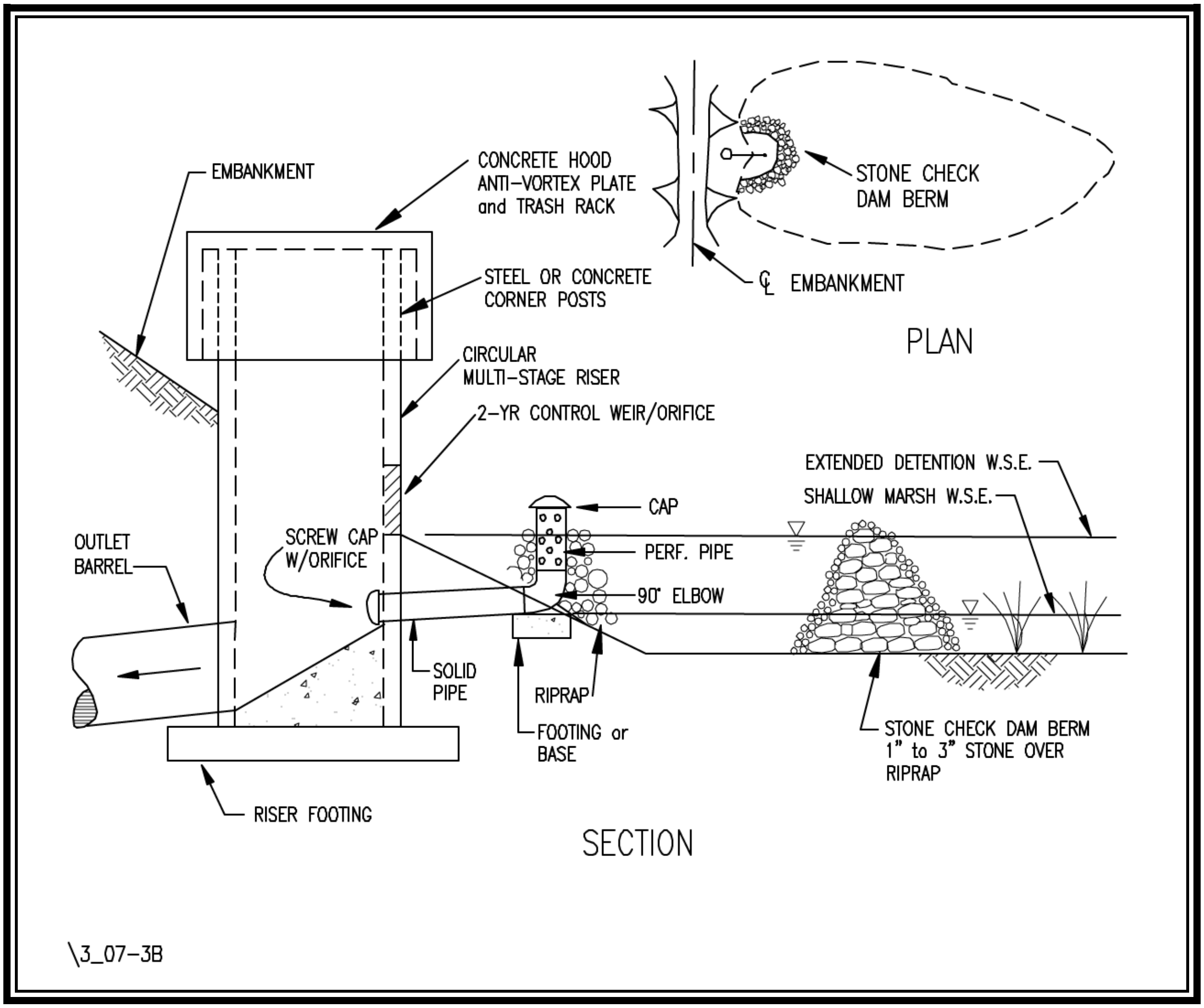
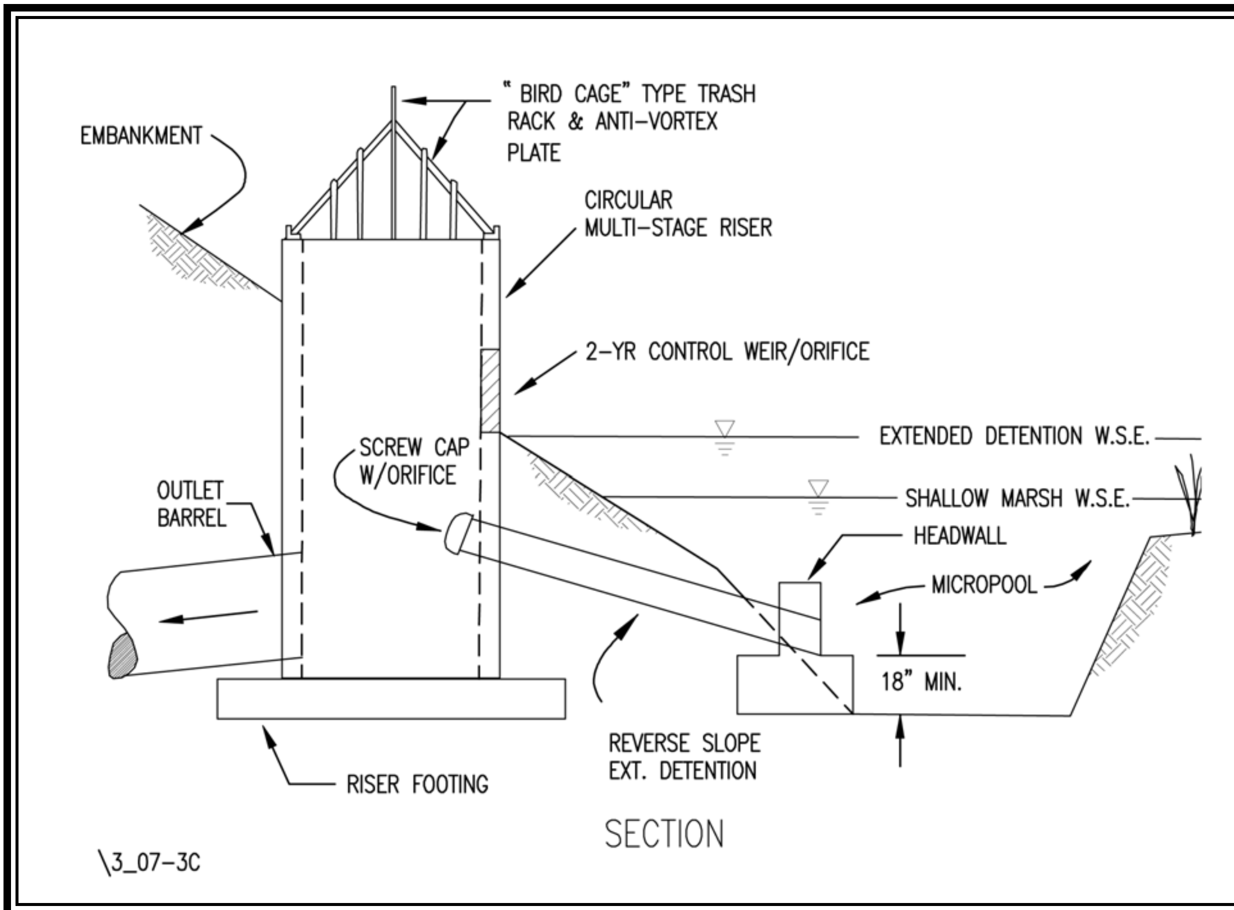


**FIGURE 3.07 - 3c**
***Trash and Debris Rack Configurations for Extended-Detention Control Structures***



## Planning Considerations

The success of an extended-detention basin is dependent on the designer's ability to identify any site and downstream conditions that may affect the design and function of the basin. Above all, the facility should be compatible with both upstream and downstream stormwater systems to promote a *watershed approach* in providing stormwater management.

The planning considerations for designing the shallow marsh of an *enhanced* extended-detention basin are very similar to those of a constructed wetland (refer to **Minimum Standard 3.09, Constructed Stormwater Wetland; Planning Considerations**).

Site conditions

Existing site conditions should be considered in the design and location of an extended-detention basin. Features such as topography, wetlands, structures, utilities, property lines, easements, etc., may impose constraints on the development. Local government land use and zoning ordinances may also specify certain requirements.

All extended-detention basins should be a minimum of 20 feet from any structure or property line, and 100 feet from any septic tank/drainfield. Extended-detention basins should also be a minimum of 50 feet from any steep slope (greater than 15%). Otherwise, a geotechnical report will be required to address the potential impact of any basin that must be constructed on or near such a slope.

Additional considerations are as follows:

1. **Soils –**

   In the past, many designs were accepted based upon soils information compiled from available data, such as SCS soil surveys. While such a source may be appropriate for a pre-engineering feasibility study, final design and acceptance **should be based on an actual subsurface analysis and a permeability test**, accompanied by appropriate engineering recommendations. The references listed at the end of this standard and at the end of **Minimum Standard 3.10, Infiltration Practices** provide more detailed information regarding the feasibility analysis of subsurface conditions for various soil types. Due to its complexity, this topic is not covered here.

   **Highly permeable soils are not suited for extended-detention basins**. A basin with highly permeable soils will act as an infiltration facility until the soils become clogged. Although this phenomenon is not always considered a negative impact, it does change the function and design of the basin. For an *enhanced* extended-detention basin, the soils must support the shallow marsh **at the time of stabilization and planting**.

A thorough analysis of the soil strata should be conducted to verify its suitability for use with an extended-detention basin. The geotechnical study required for the embankment design (refer to **Minimum Standard 3.01, Earthen Embankment**) will often provide adequate data for this purpose. The soil permeability may be such that the basin can support a shallow marsh. However, as the depth of the temporary storage increases, the increased head or pressure on the soil may increase the rate of infiltration. If necessary, a liner of clay, geosynthetic fabric, or other suitable material may be used in the basin (as specified by a geotechnical engineer). Refer to the design criteria for basin liners.

2. **Rock –**

The subsurface investigation should also identify the presence of rock or bedrock. Excavation of rock may be too expensive or difficult with conventional earth moving equipment.Blasting the rock for removal may be possible, but it may also open seams or create cracks in the underlying rock, resulting in an unwanted drawdown of the shallow marsh. Blasting of rock is not recommended unless a liner, as described above, is used.

3. **Karst –**

In regions where Karst topography is prevalent, projects may require thorough soils investigation and specialized design and construction techniques. Since the presence of karst may affect BMP selection, design, and cost, a site should be evaluated **during the planning phase of the project**.

4. **Existing Utilities –**

Most utility companies will not allow a permanent or temporary pool to be installed over their underground lines or right-of-ways. If such a site must be used, the designer should obtain permission from the utility company **before designing the basin**. The relocation of any existing utilities should be researched and the costs included in the overall basin cost estimate.

Environmental Impacts

1. **Wetlands–**

Large facilities and/or regional facilities lend themselves to being placed in low lying, and usually environmentally sensitive, areas. Such locations often contain wetlands, shallow marshes, perennial streams, wildlife habitat, etc., and may be protected by state or federal laws. The owner or designer should investigate the regional wetland maps and contact appropriate local, state, and federal agencies to verify the presence of wetlands, their protected status, and the suitability for an extended-detention basin at the location in question.

With careful planning, it may be possible to incorporate wetland mitigation into an extended-detention basin design. This assumes that the functional value of the existing or impacted wetland can be identified and included, reconstructed, or mitigated for, in the basin. Contact the Virginia Department of Environmental Quality for more information regarding wetland mitigation.

2. **Downstream Impacts–**

Urban detention and retention basin design should be coordinated with a watershed or regional plan for managing stormwater runoff, if available. In a localized situation, an individual basin can provide effective protection for the downstream channel if no other areas contribute runoff in a detrimental way to the channel. However, an uncontrolled increase in the number of impoundments within a watershed can severely alter natural flow conditions, causing combined flow peaks or increased flow duration. This can ultimately lead to flooding downstream degradation.

3. **Upstream Impacts–**

The upstream channel must also be considered, especially when the extended-detention basin is used to control downstream channel erosion. Erosive upstream flows will not only degrade the upstream channel, but will also significantly increase the maintenance requirements in the basin by depositing large amounts of sediment eroded from the channel bottom.

Water Quality Enhancement

In an extended-detention basin, the quality of the incoming stormwater is improved through *gravitational settling* of pollutants from the water quality volume. The pollutant removal efficiency for *soluble* pollutants is usually much **lower** than for *particulate pollutants*. Therefore, the efficiency of an extended-detention basin can be **enhanced** by adding a *shallow marsh* to the lower stage of the basin. The shallow marsh creates physical and biological characteristics that are more conducive to the removal process for soluble pollutants.

Settling column studies suggest a maximum upper limit of approximately 40 to 50% removal for total phosphorous after 48 hours, with most of the removal occurring within the first 6 to 12 hours (MWCOG, 1987). However, field studies show a much broader range in removing phosphorous (15-70%) and in removing sediment (65%). Since the soluble form of phosphorous comprises nearly half the phosphorous found in urban runoff, the lower efficiency of 35% (**Table 3.07-1**) is deemed appropriate. The increase in efficiency of *enhanced* extended-detention is attributed to the ability of the shallow marsh to reduce the soluble pollutant levels.

Providing a larger extended-detention volume (similar to providing a larger permanent pool for a retention basin) may not increase the pollutant removal efficiency. **Increasing the volume without increasing the detention time results in a larger orifice size and, therefore, less control of the smaller "first flush" storms**. Simply increasing the detention time will not provide additional efficiency either, since the 30-hour drawdown period exceeds the *probable settling time* associated with most particulate pollutants.

The pollutant removal efficiency in an *enhanced* extended-detention basin **can** be increased, however, by enlarging the volume of the shallow marsh. As the volume of the marsh is increased, with respect to the contributing drainage area, the *hydraulic residence time* is increased. This longer residence time provides more opportunity for further biological uptake and decomposition of pollutants.

Flooding and Channel Erosion Control

Flood control and downstream channel erosion are managed by storing additional runoff above the extended-detention pool (and shallow marsh) and by properly sizing the discharge opening in the riser structure.

When selecting an extended-detention basin, the biggest concern is how much land it requires. The storage volume needed above the extended-detention pool (and shallow marsh) must be approximated and its availability verified on the preliminary site plan.

*A preliminary sizing estimate is recommended **during the planning stage** to verify the feasibility of using an extended-detention basin. (See **Chapter 5, Engineering Calculations** for Storage Volume Requirement Estimates).*

Sediment Control

An extended-detention basin may be used as a *temporary sediment control basin* during construction. The design of a temporary sediment basin is based on the *maximum drainage area* and *rate of runoff* expected anytime during the site construction process. In contrast, the design of the permanent stormwater basin is based on *post-developed land use conditions*. When designing a basin to provide both temporary sediment control and permanent stormwater management, the criteria that produces the largest storage volume should be used to size the basin. The discharge structure should be designed as a permanent stormwater facility with respect to its riser and barrel hydraulics and materials. The riser's geometry may then be temporarily modified to provide the wet and dry storage for the temporary sediment basin, as required by VESCH, 1992 edition.

Safety

Basins that are readily accessible to populated areas should include all possible safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter should be avoided and dangerous outlet facilities should be protected by enclosures. Warning signs for temporary deep water conditions and potential health risks should be used wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks or paths. A dry basin may hold a significant amount of soft sediment in the bottom, posing a danger to small children.

A fence is required at or above the maximum water surface elevation when a basin slope is a vertical wall. Local governments and homeowners associations may also require appropriate fencing despite the steepness of the basin side slopes.

Maintenance

Extended-detention basins have shown an ability to function as designed for long periods without routine maintenance. However, some maintenance is essential to protect the aesthetic properties of these facilities.

Vehicular access to the sediment forebay and the release structure should be provided to allow for long-term maintenance (such as sediment removal) and repairs, as needed. The use of a sediment forebay at the upstream end of the basin will help to localize the disturbance during routine sediment removal operations. An onsite area designated for sediment dewatering and disposal should also be included in the design. Care must be taken in the disposal of sediment that may contain an accumulation of heavy metals. **Sediment testing is recommended prior to sediment removal to assure proper disposal**.

A sign should be posted near the basin that clearly identifies the person or organization responsible for basin maintenance. Allowing participation by adjacent landowners or visitors is very helpful, especially if the facility is used for recreation. Maintenance items observed and addressed early will

help to limit overall maintenance costs. Routine maintenance inspections, however, should be conducted by authorized personnel
.

## Design Criteria

This section provides recommendations and minimum criteria for the design of extended-detention and *enhanced* extended-detention basins intended to comply with the Virginia Stormwater Management program. It is the designer's responsibility to decide which aspects of the program are applicable to the particular facility being designed and to decide if any additional design elements are required. The designer should also consider the long-term functioning of the facility when selecting materials for the structural components.

### Hydrology and Hydraulics

The pre- and post-developed hydrology for a basin's contributing watershed, the hydraulic analysis of the riser and barrel system, and the emergency spillway design should be developed using **Chapter 4, Hydrologic Methods** and **Chapter 5, Engineering Calculations**.

Generally, the 2-year storm should be used in *receiving channel adequacy* calculations and the 10-year storm should be used for *flood control* calculations. Alternate requirements, such as 1-year extended detention for channel erosion control may be imposed by local ordinances.

### Embankment

The design of the earthen embankment for an extended-detention and *enhanced* extended-detention basin should comply with **Minimum Standard 3.01, Earthen Embankment**. The requirements for geotechnical, seepage control, maximum slope, and freeboard are particularly appropriate.

### Principal Spillway

The design of the principal spillway and barrel system, anti-vortex device, and trash racks should comply with **Minimum Standard 3.02, Principal Spillway**.

Emergency Spillway

An emergency spillway that complies with **Minimum Standard 3.03, Vegetated Emergency Spillway** should be provided when possible, or appropriate.

Sediment Basin Conversion

**When a proposed stormwater facility is used initially as a temporary sediment basin, conversion to the permanent facility should be completed after final stabilization and approval from the appropriate erosion and sediment control authority**.

Sometimes, the temporary sediment basin design criteria will require more storage volume than that of a stormwater basin. In such cases, the extra volume may be allocated to the component of the facility that would derive the greatest benefit from increased storage. This will depend on the primary function of the facility (i.e., water quality enhancement, flood control, or channel erosion control).

If modifications to the riser structure are required as part of the conversion to a permanent basin, they should be designed so that a) *the structural integrity of the riser is not threatened*, and b) *large construction equipment is not needed within the basin*. Any heavy construction work required on the riser should be completed during its initial installation. It is **NOT** recommended to install a temporary sediment basin riser structure in the basin and then replace it with a permanent riser after final stabilization. This may affect the structural integrity of the existing embankment and barrel.

The following additional criteria should be considered for a conversion:

1. Final elevations and a complete description of any modifications to the riser structure geometry should be shown on the approved plans.

2. The wet storage area must be dewatered following the approved methods in VESCH, 1992 edition.

3. Sediment and other debris should be removed to a contained spoil area. Regrading of the basin may be necessary to achieve the final design grades and to provide an adequate topsoil layer to promote final stabilization.

4. Final modifications to the riser structure should be carefully inspected for water tight connections and compliance with the approved plans.

5. Final landscaping and stabilization should be per VESCH, 1992 edition, and **Minimum Standard 3.05, Landscaping** in this manual. Establishing vegetation may prove difficult if flow is routed through the facility prior to germination. In such cases, specifying sod or other reinforcements for the basin bottom and low flow channels may be appropriate.

Extended-Detention Volume

*Water quality* extended-detention basins are designed to allow particulate pollutants to settle out of water quality volume. **Chapter 5, Engineering Calculations** provides calculation procedures for determining the *water quality volume* for a particular watershed, and for sizing the release orifice to provide the required 30-hour draw down. **The water quality volume is the first one-half inch of runoff from the impervious surfaces**.

*Channel erosion control* extended-detention basins are designed to reduce the rate of discharge such that the velocity is below the critical velocity for the downstream channel. **Chapter 5, Engineering Calculations** provides the calculation procedures for calculating the *channel erosion control volume* for a particular watershed, and for sizing the release structure to provide the required 24-hour draw down. **The channel erosion control volume is the runoff generated from the drainage area or watershed by the 1-year frequency design storm.**

The orifice sizing procedure for extended detention is based on a "*brim*" drawdown. The full design volume is assumed to be in the basin, and the drawdown period is the time it takes to drain that entire volume. In reality, this technique ignores the *routing effect* that occurs in the basin: as the runoff volume accumulates, stormwater is draining into the basin while simultaneously draining out of it. For small storms, the extended-detention volume will never fill to the "brim" and will, therefore, never achieve the maximum drawdown time.

The calculation procedure used to verify the draw down time is presented in **Chapter 5.** The extended-detention volume (in cubic feet) is divided by the maximum release rate (in cubic feet per second), which is based on the maximum hydraulic head associated with the water quality volume, to give the *detention time*, in seconds. Using the maximum release rate, rather than the average release rate, results in a smaller orifice, which helps to compensate for ignoring the routing effect, as discussed above.

*Enhanced* Extended-Detention Basin: Shallow Marsh

When a higher pollutant removal efficiency is needed, a water quality extended-detention basin can be enhanced by providing a *shallow marsh* in the bottom of the facility. The use of a shallow marsh limits the maximum range of vertical storage in the extended-detention pool to 3 feet above the marsh's water surface elevation. However, the surface area requirements for the shallow marsh will likely force the basin's geometry to broaden at the lower stages, which will compensate for the reduced vertical storage. Extended-detention water surface elevations greater than 3 feet, and the frequency at which those elevations can be expected, are not conducive to the growth of dense or diverse stands of emergent wetland plants.

Similar to the permanent pool of a constructed wetland, the shallow marsh in the bottom of an extended-detention basin should be designed to maximize pollutant removal efficiency. The physical and hydraulic factors that can influence the pollutant removal efficiency of a shallow marsh are: 1) *volume*, 2) *depth*, 3) *surface area*, 4) *geometry*, and 5) *hydraulic residence time*. In addition, careful attention should be given to the landscaping plan (refer to **Minimum Standard 3.09, Constructed Wetland** for design criteria regarding the establishment of vegetation in a shallow marsh.

The following criteria are general guidelines. The depth of the treatment volume and amount of surface area varies with each site and the intended secondary functions of the facility (i.e., providing habitat, aesthetics, etc.).

1. **Volume–**

The pool volume of an extended-detention shallow marsh varies with the water quality volume. The water quality volume (WQV), as defined by Virginia Stormwater Management regulations, is the **first one-half inch of runoff, multiplied by the area of impervious surface**. The target pollutant removal efficiency of an *enhanced* extended-detention basin, as presented in **Table 3.07-1**, is based on 2.0 times the WQV. The shallow marsh pool volume represents 1.0 × WQV and the extended-detention volume represents an additional 1.0 × WQV. The pollutant removal efficiency is directly related to the percentage of runoff available to be treated. If it is assumed that all of the rainfall that hits impervious surfaces turns into runoff (ignoring minor losses such as evaporation, depression storage, etc.), then a design volume of 2.0 × WQV represents a design storm of 1 inch of rainfall. Based upon available rainfall data from the Washington, D.C. area, 1 inch of rainfall represents approximately 85% of all runoff producing storm events (MWCOG, 1992). Therefore, 2.0 × WQV (or 1 inch of rainfall from impervious surfaces) represents a significant percentage of runoff producing events.

2. **Depth–**

The treatment volume of a shallow marsh should occupy different depth zones, as shown in **Table 3.07-2**, to maximize the physical and biological processes that occur within the marsh. Three basic depth zones should be used: a) *deep pools*, b) *low-marsh*, and c) *high-marsh*.

a. Deep pool areas should be 1.5 to 4 feet deep and may consist of 1) *sediment forebays*, 2) *micro-pools*, and 3) *deep water channels*.

1. A sediment forebay is highly recommended in a shallow marsh. It should be constructed near incoming pipes or channels to reduce the velocity of incoming runoff, trap course sediments, and spread the runoff evenly over the marsh area. The forebay should be constructed as a separate cell from the rest of the marsh, with maintenance access provided to simplify cleaning with heavy equipment (refer to **Minimum Standard 3.04, Sediment Forebay**).

2. A micro-pool should be a standard component of the extended-detention shallow marsh. The purpose of a micro-pool is to create sufficient depth near

the outlet to help reduce clogging of the extended detention orifice. This will allow for a reverse-sloped pipe to extend into the marsh below the pool surface elevation but above the pool bottom which helps to prevent clogging, since a typical marsh environment consists of floating plant debris and possible sediment and organic accumulation on the bottom. Micro-pools also provide open water areas to attract plant and wildlife diversity (refer to the **Overflow** discussion later in this section).

3. Deep water channels provide an opportunity to lengthen the flow path to avoid seasonal short-circuiting (refer to the **Geometry** discussion later in this standard.)

b. Low-marsh zones range in depth from 6 to 18 inches.

c. High-marsh zones range in depth from 0 to 6 inches. The high-marsh zone will typically support the greatest density and diversity of emergent plant species.

3. **Surface Area–**

At a minimum, the surface area of an extended-detention shallow marsh should be sized to equal 1% of the contributing drainage area. The recommended surface area allocation for the different depth zones is presented in **Table 3.07-2** (MWCOG, 1992). Note that the surface area criteria may create a conflict with the volume allocations. If this happens, the designer is reminded that these are recommendations. **The criteria that establish the largest permanent pool should be used**.

4. **Geometry–**

The geometry of the shallow marsh must be carefully designed to avoid *short-circuiting*. Meandering, rather than straight line flow is desirable. Maximum pollutant removal efficiencies will be achieved due to the increased contact time associated with the longest possible flow path through the marsh. A length-to-width ratio of 2:1 through the marsh should be maintained (see **Figure 3.07-4**). The length-to-width ratio is calculated by dividing the straight line distance from the inlet to the outlet by the marsh's average width.

**TABLE 3.07 - 2**
***Recommended Allocation of Surface Area and Treatment Volume for Depth Zones***

| Depth Zone | % of Surface Area | % of Treatment Volume |
|---|---|---|
| *Deep Water* 1.5 to 4 feet in depth (forebay and micro-pool) | 20 | 40 |
| *Low Marsh* 0.5 to 1.5 feet in depth | 40 | 40 |
| *High Marsh* 0 to 0.5 feet | 40 | 20 |

*(Adapted from MWCOG, 1992)*

5. **Hydraulic Residence Time–**

The *hydraulic residence time* is the shallow marsh pool volume divided by the average outflow discharge rate. The longer the residence time, the higher the pollutant removal efficiency (Driscoll, 1983, Kulzer, 1989).

In theory, by using 1.0 x WQV in sizing the shallow marsh volume, the smaller storms (those producing ½ inch of runoff or less) will displace the pool volume of the marsh. However, larger treatment volumes (such as 2 or 3 x WQV), compared with the watershed size, will provide longer residence times and greater efficiencies. In certain situations, increasing the target pollutant removal efficiency by using a higher water quality volume multiplier to size the marsh volume may be acceptable. However, the challenge will be to provide the recommended depth zone allocations for the allocated percentages of surface area and treatment volumes, as previously discussed.

Base Flow

The presence of a *base flow* makes the design of an extended-detention control structure difficult. If the extended-detention orifice is sized for the *wet weather base flow*, then the dry weather control is compromised because the release rate is too high. If the orifice is undersized to maintain the *dry weather control*, then the extended-detention pool may remain full of water during the wet weather season; this essentially eliminates the extended-detention volume by creating an undersized permanent pool (1.0 x WQV). When seasonal base flow is present, an adjustable orifice should be provided in the control structure to maintain the marsh volume.

The presence of a base flow and the associated potential for erosion within the basin should be considered in the design. Ideally, base flow, or *low flows*, should be spread out so that they *sheet flow* across the bottom of the basin. Due to maintenance difficulties and undesirable insect breeding associated with standing water, some localities may have ordinances that require *low-flow channels* (or *trickle ditches*) to carry base flows. If an *impervious* ditch is used to convey base flows, it should be designed to overflow during storm events and spread the runoff across the basin floor. The use of gabion baskets or riprap, instead of concrete, may provide the advantage of slowing the flow, encouraging spillover onto the basin floor. **Generally, an impervious low-flow channel is <u>NOT</u> recommended in a stormwater management water quality basin, as its use is contrary to the basin's water quality function**.

Local ordinances should be reviewed for specific requirements relating to low-flow or base-flow channels in dry detention basins.

<u>Overflow</u>

Similar to a constructed stormwater wetland, an extended-detention overflow system should be designed to provide adequate overflow or bypass for a full range of design storms. For an *enhanced* extended-detention basin, the overflow system should pass the full range of design storms with no more than 3 feet of hydraulic head above the shallow marsh.

<u>Sediment Forebay</u>

A sediment forebay will help to postpone overall basin maintenance by trapping incoming sediments at a specified location. The forebay should be situated and designed per **Minimum Standard 3.04, Sediment Forebay**. Usually, a sediment forebay is placed at the outfall of the incoming storm drain pipes and positioned to ensure access for maintenance equipment.

A sediment forebay enhances the pollutant removal efficiency of a basin by trapping the incoming sediment load in one area where it can be easily monitored and removed. For an *enhanced* extended-detention basin, the sediment forebay is included in the deep pool allocations of the surface area and storage volume. The target pollutant removal efficiency of an extended-detention basin, as listed in **Table 3.07-1**, is predicated on using a sediment forebay at the inflow points of the basin.

<u>Liner to Prevent Infiltration</u>

Extended-detention basins should have negligible infiltration rates through the bottom of the basin. Infiltration will impair the proper functioning of the basin and may contaminate groundwater, and in areas of Karst, may cause collapse. For an *enhanced* extended-detention basin, excessive infiltration may prevent the shallow marsh from holding water. If infiltration is anticipated, and the area is not suspected to be underlain by Karst, than an infiltration facility, rather than a detention water quality BMP, should be used **<u>or</u>** a liner should be installed in the basin to prevent infiltration.

When using a liner, the following recommendations apply:

1. A clay liner should have a minimum thickness of 12 inches and should comply with the specifications provided in **Table 3.07-3**.

2. A layer of compacted topsoil (minimum 6 to 12 inches thick) should be placed over the liner before seeding with an appropriate seed mixture (refer to VESCH, 1992 edition)

3. Other liner types may be used if supporting documentation is provided verifying the liner material's performance.

**TABLE 3.07 - 3**
***Clay Liner Specifications***

| Property | Test Method (or equal) | Unit | Specification |
|---|---|---|---|
| Permeability | ASTM D-2434 | *cm/sec* | $1 \times 10^{-6}$ |
| Plasticity Index of Clay | ASTM D-423 & D-424 | % | Not less than 15 |
| Liquid Limit of Clay | ASTM D-2216 | % | Not less than 30 |
| Clay Particles Passing | ASTM D-422 | % | Not less than 30 |
| Clay Compaction | ASTM D-2216 | % | 95% of Standard Proctor Density |

*Source: City of Austin, 1988*

Access

A 10 to 12 foot wide access road with a maximum grade of 12% should be provided to allow vehicular access to both the outlet structure area and at least one side of the basin. The road's surface material should be selected to support the anticipated frequency of use and vehicular load without excessive erosion or damage.

Landscaping

A qualified individual should prepare the landscape plan for an extended-detention basin. Appropriate shoreline fringe, riparian fringe and floodplain terrace vegetation must be selected to correspond with the expected frequency and duration of inundation. Additional criteria for landscaping may be found in **Minimum Standard 3.05, Landscaping**. For establishment of vegetation in the marsh area, refer to **Minimum Standard 3.09, Constructed Wetland**.

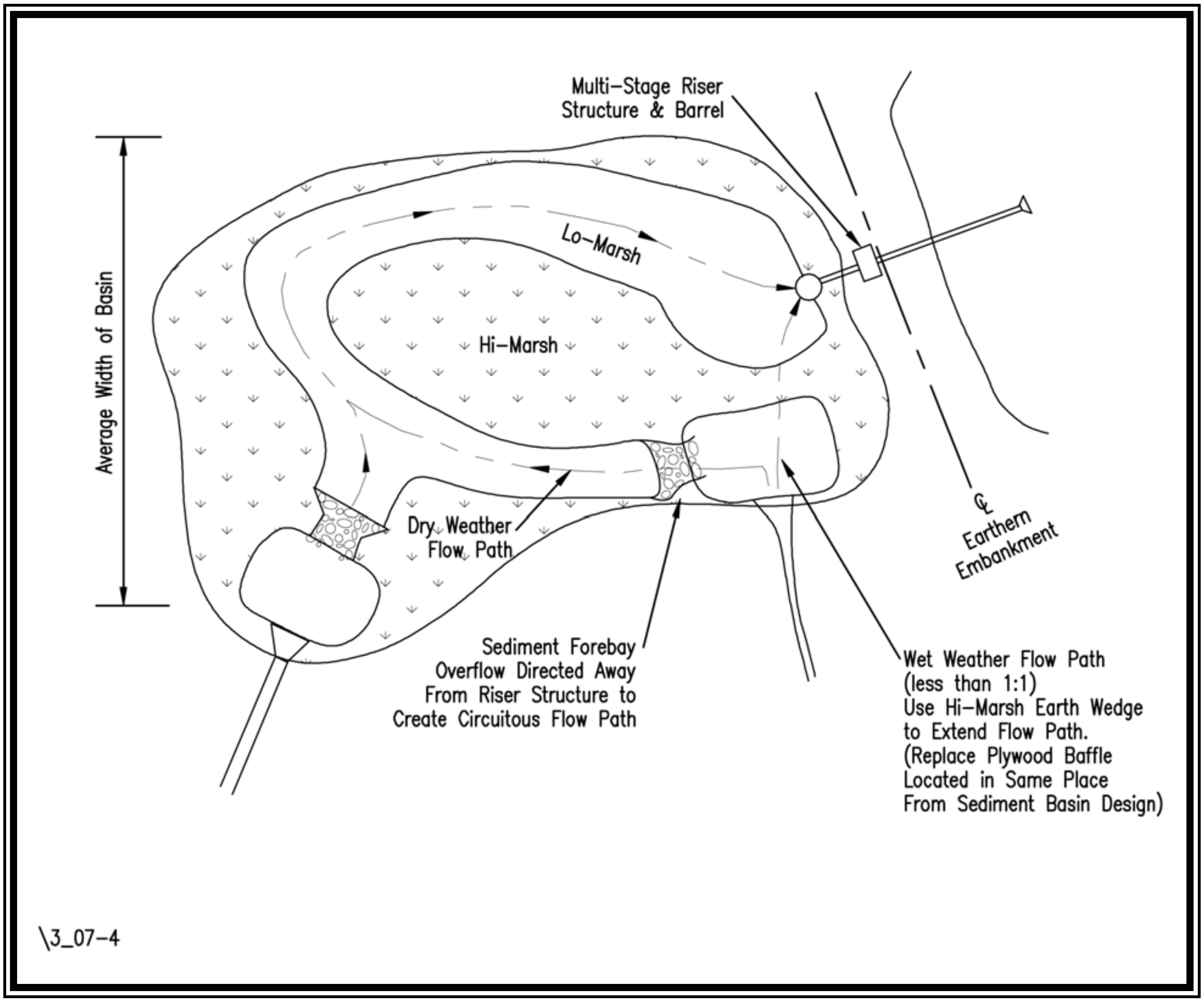
The vegetation should be planted in soil that is appropriate for the plants selected. Soil tests showing the adequacy of the soil or a soil enhancement plan should be submitted with the overall basin design.

The soil substrate must be soft enough to permit easy installation of the plants. If the basin soil has been compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked before planting. If soil is imported, it should be laid at least 6 inches deep to provide sufficient depth for plant rooting to occur.

Buffer Zone

A vegetated buffer strip should be maintained beside the basin. The strip should be a minimum of 20 feet wide, as measured from the maximum water surface elevation. Refer to **Minimum Standard 3.05, Landscaping**.

**FIGURE 3.07 - 4**
*Flow Path/Short-Circuiting*



## Construction Specifications

The construction specifications for stormwater extended-detention and *enhanced* extended-detention basins outlined below should be considered minimum guidelines. More stringent or additional specifications may be required based on individual site conditions.

Overall, widely accepted construction standards and specifications for embankment ponds, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed to build an impoundment.

Further guidance can be found in Chapter 17 of the Soil Conservation Service's <u>Engineering Field Manual</u>. Specifications for the work should conform to methods and procedures specified for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry and any other items that apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local plan approving authority.

The following minimum standards contain guidance and construction specifications for various components of these facilities: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; **3.05, Landscaping**, and **3:09, Constructed Wetland**.

## Maintenance and Inspections

The following maintenance
and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here. The engineer is responsible for determining if any additional items are necessary.

Inspecting and maintaining the structures and the impoundment area should be the responsibility of the local government, a designated group such as a homeowner association, or an individual. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations.

<u>General Maintenance</u>

Maintenance and inspection guidelines found in the following minimum standards also apply: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**, and **3.05, Landscaping**.

Vegetation

The basin's side slopes, embankment and emergency spillway should be mowed at least twice a year to discourage woody growth. More frequent mowing may be necessary in residential areas for aesthetic purposes.

Dry extended-detention basins may have soggy bottoms, making mowing costly and difficult. The use of water-tolerant, hardy, and slow growing grass is recommended for the bottom of these basins. **Vegetation is preferred to an impervious low-flow channel since the channel may interfere with the pollution removal capabilities of the basin**. The designer should be aware of local program requirements, as some localities require low-flow channels.

Specific plant communities may require different levels of maintenance. Upland and floodplain terrace areas, grown as meadows or forests, require very little maintenance, while aquatic or emergent vegetation may need periodic thinning or reinforcement plantings. Note that after the first growing season it should be obvious if reinforcement plantings are needed. If they are, they should be installed at the onset of the second growing season after construction.

Research indicates that for most aquatic plants the uptake of pollutants is stored in the roots, not the stems and leaves (Lepp 1981). Therefore, aquatic plants should not require harvesting before winter plant die-back. There are still many unanswered questions about the long term pollutant storage capacity of plants. Possible aquatic and emergent plant maintenance recommendations may be presented in the future.

Debris and Litter Removal

Debris and litter will accumulate near the inflow points and around the outlet control structure. Such material should be removed periodically. Significant accumulation can clog the low-flow outlet and the upper control openings.

Sediment Removal

Sediment deposition should be continually monitored in the basin. Removal of accumulated sediment is extremely important. A significant accumulation of sediment impairs the pollutant removal capabilities of the basin by reducing the available storage for the water quality volume and/or reducing the available volume for the shallow marsh. In addition, accumulated sediment in the bottom of a basin creates unsightly conditions and chokes out established vegetation.

Unless unusual conditions exist, it is anticipated that accumulated sediment will need to be removed from the basin every 5 to 10 years (MWCOG, 1987). More frequent cleaning of the area around the low flow or extended-detention orifice may be required. The use of a sediment forebay with access for heavy equipment will greatly simplify the removal process. **During maintenance procedures,**

**ensure that any pumping of standing water or dewatering of dredged sediments complies with the VESCH, 1992 edition, and any local requirements**.

Owners, operators, and maintenance authorities should be aware that significant concentrations of heavy metals (e.g., lead, zinc and cadmium) and some organics, such as pesticides, may be expected to accumulate at the bottom of a basin. Testing of sediment, especially near points of inflow, should be conducted regularly and **before disposal** to find the leaching potential and level of accumulation of hazardous materials. Disposal methods must comply with the health department requirements of the local government.

Inspections

An extended-detention basin and its components should be inspected annually to ensure that they operate in the manner originally intended. If possible, inspections should be conducted during wet weather to determine if the extended-detention time is being achieved. Inspections should be conducted by a qualified individual following the checklist provided in **Chapter 3 Appendix**.

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Extended Detention Basin – full. Note circuitous flow path.

Enhanced Extended Detention Basin – Shallow Marsh. Note multi-stage weir principal spillway and deep water pool (18” – 48” depth).

# Extended-Detention Basin & Enhanced Extended-Detention Basin

Extended Detention Basin – empty.

Extended Detention Basin – full.

# Extended-Detention Basin & Enhanced Extended-Detention Basin

*MINIMUM STANDARD 3.09*

# CONSTRUCTED STORMWATER WETLAND

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.09

# CONSTRUCTED STORMWATER WETLAND

### Definition

Constructed stormwater wetlands are manmade shallow pools that create growing conditions suitable for both emergent and aquatic vegetation.

### Purpose

*Constructed wetlands* are intentionally installed on non-wetland sites to enhance the quality of stormwater runoff.

In contrast, *created wetlands* are also intentionally installed on non-wetland sites, but are designed to produce or replace natural functional wetlands and wetland habitats (e.g., for compensatory mitigation projects).

This handbook deals primarily with *constructed wetlands*. Sometimes, a constructed wetland may provide some of the benefits of a created wetland. However, understanding the differences in these two manmade systems is important. For a *natural* or *created wetland*, pre-treatment BMPs, such as erosion controls, presettling basins, biofilters, etc., are used to reduce pollutants entering the wetland to prevent its degradation and clogging. The primary function of a *constructed wetland,* on the other hand, is to provide those same types of pre-treatment functions within the wetland itself. The constructed wetland, therefore, will require maintenance to assure long-term pollutant removal. **It should be noted that the pre-treatment BMPs mentioned above will often simplify or reduce maintenance requirements, as well as enhance and prolong the useful life of a constructed stormwater wetland.**

Water Quality Enhancement

A constructed stormwater wetland can achieve high removal rates of particulate and soluble pollutants (nutrients) through gravitational settling, wetland plant uptake, absorption, physical filtration, and biological decomposition. The pollutant removal efficiency of a constructed wetland is dependent on various design criteria relating to the size and design of the pool area. Other site-specific design features and variations in environmental conditions such as soils, climate, hydrology, etc. make it difficult to predict the actual pollutant removal efficiency. Monitoring of many stormwater wetland facilities has confirmed the wide range of pollutant removal efficiencies associated with such systems.

Constructed stormwater wetlands operate similar to retention basins, yet their overall performance is expected to be more variable. This may be due to any of the following:

1. The decrease in biological activity associated with seasonal cold weather.

2. The conversion of plant species and densities as the wetland matures and becomes acclimated to various environmental factors such as soils, hydrology, climate, and sediment and pollutant load.

3. The uncertainty of the biological cycling processes of phosphorous in the wetland environment.

The expected pollutant removal rate of constructed stormwater wetlands is provided in **Table 3.09-1**. While the rate may appear low, it reflects the uncertainty of their long-term viability.

**TABLE 3.09 - 1**
***Pollutant Removal Efficiency for Constructed Stormwater Wetlands***

| **Water Quality BMP** | **Target Phosphorus Removal Efficiency** | **Impervious Cover** |
|---|---|---|
| Constructed Wetlands 2.0 x WQ Volume | 30% | 22 - 37% |

<u>Flood Control & Channel Erosion Control</u>

Constructed stormwater wetlands should generally not be used for flood control or stream channel erosion control. This is due to the anticipated water level fluctuations associated with quantity controls. The clearing of vegetation and the addition of impervious surfaces may cause large and sudden surges of runoff during rain events, and may cause less than normal base flows due to lack of groundwater during dry periods. Large, sudden fluctuations in water levels can stress emergent wetland and upland edge vegetation. Most edge vegetation cannot survive drought or saturation extremes, leaving wetland banks exposed to potential erosion. It should be noted that the large surface area requirement for constructed stormwater wetlands will help to minimize the "extreme" water level fluctuations during all but the larger storm events. Also, certain plants can be specified for the upland banks which may be more tolerant to the wet and dry extremes. Therefore, preventing surges whenever possible and designing for gradual increases and decreases in water level is important for successful constructed wetland design. See **Design Criteria** for further discussion.

(Wetland vegetation can be used to enhance the pollutant removal efficiency of extended-detention flood control and stream channel erosion control facilities by constructing a shallow marsh in their bottoms. See **Minimum Standard 3.07, Extended-Detention and *Enhanced* Extended-Detention Basin**.)

## Conditions Where Practice Applies

Drainage Area

The drainage area criteria for a constructed stormwater wetland is similar to that of a retention basin. However, because of their shallow depth, constructed stormwater wetlands may consume two to three times the site area compared with other stormwater quality BMPs (MWCOG, 1992). Vertical (depth) storage is usually not possible in constructed wetlands due to the needs of aquatic plants. Therefore, the maximum watershed size depends on the available area on the site that is suitable for a constructed wetland system.

The minimum watershed drainage area for constructed stormwater wetlands should be 10 acres. However, this minimum should be confirmed based on the watershed's hydrology and the presence of an adequate base flow to support the selected vegetation. Similar to retention basins, a drainage area of 15 to 20 acres or the presence of a dependable base flow is most desirable to maintain a healthy wetland. A clay liner may be necessary to prevent infiltration if losses are expected to be high.

Development Conditions

Constructed stormwater wetlands are suited for both low- and high-visibility sites. However, the aesthetic problems associated with having a natural and free growing landscape feature in an otherwise manicured development setting should be avoided for high-visibility sites. Additional concerns regarding stagnation or excessive infiltration during the dry summer months may also influence the choice of location. Proper planning, design, and maintenance are critical to ensure the pollutant removal capabilities of a constructed wetland and to insure its acceptance by adjacent landowners.

Like retention basins, constructed wetlands are also suited for low- and medium-density residential or commercial developments. However, the land area required for this BMP may limit its use.

## Planning Considerations

Constructed stormwater wetlands should be designed to duplicate the functions of natural wetlands, while allowing for ongoing maintenance. The designer faces the difficult task of replicating natural wetland hydrology in a constructed setting, while ensuring easy access for maintenance.

Hydrology

The hydrology of a constructed stormwater wetland is largely influenced by surface runoff. The hydrology, in turn, affects several key characteristics of a stormwater wetland, such as:

1. *Water level fluctuations*. A *constructed stormwater* wetland will experience rapid inundation and drawdown periods with each runoff-producing event.

2. *Permanent pool*. A *natural* wetland may experience seasonal standing water and/or periodic drawdowns. However, a constructed stormwater wetland is engineered to permanently hold a specific volume of water, or at a minimum, maintain pools of water of varying depths. This stored water supports the aquatic and emergent plant regime and maintains the pollutant removal efficiency of the BMP.

3. *Vegetation*. The vegetation diversity in a constructed wetland is established by the landscape plan or volunteer vegetation. The selection of vegetation should be limited to native plant species suitable for the pool depths expected within the different depth zones. Care should be taken to avoid the introduction of exotic or invasive species. The use of appropriate donor soil and wetland mulch will help prevent this problem.

   In contrast, a natural wetland vegetates itself through natural selection based on the growing conditions within it. The existing source of seeds, which is usually enhanced by wildlife, allows for the constant renewal of plant life.

4. *Sediment and pollutant load*. A stormwater wetland is subject to sediment loads, especially from upland pervious areas during the first growing season. During this period, permanent vegetation in the developing watershed is still growing. Without a well-established ground cover, surface sediments can be easily transported by rainfall and resulting runoff. Accumulation of this sediment in the constructed stormwater wetland during the first growing season alone can dramatically alter the topography of the facility, affecting water levels and flow paths. Furthermore, the pollutant load (nutrients and organics) associated with urban runoff and sediments entering a constructed wetland is usually higher than that which enters a natural or undisturbed wetland in undeveloped watershed. Therefore, if the constructed wetland is used to remove pollutants, the water quality within the wetland itself will be decreased. During the planning stage of a facility, the designer should have a good understanding of site-specific runoff constituents and an understanding of their possible effects on the selected vegetation.

Site Conditions

Site conditions, such as property lines, easements, utilities, structures, etc., that may impose constraints on development should be considered when designing a constructed wetland. Local government land use and zoning ordinances may also specify certain requirements.

All facilities should be a minimum of 20 feet from any structure, property line, or vegetative buffer, and 100 feet from any septic tank/drainfield. Local landuse setbacks and other restrictions may apply.

All facilities should be a minimum of 50 feet from any steep slope (greater than 10%). Alternatively, a site-specific geotechnical report must address the potential impact of a constructed stormwater wetland that is to be installed on, or near, such a slope.

Additional considerations are as follows:

1. **Soils–**

   **Permeable soils are not suited for constructed stormwater wetlands**. A thorough analysis of the soil strata should be conducted to verify its suitability for holding water. In the past, many BMP designs were accepted based upon soils information compiled from available data, such as SCS soil surveys. While such a source may be appropriate for a pre-engineering feasibility study, final design and acceptance **should be based on an actual subsurface analysis and permeability tests**, accompanied by appropriate engineering recommendations. Refer to the references listed at the end of **Minimum Standard 3.10, Infiltration Practices** for additional information on soil analysis techniques.

   The goal of a subsurface analysis is to determine if the soils are suitable for a constructed stormwater wetland. The textural character of the soil horizons and/or strata units within the subsoil profile should be identified to at least 3 feet below the bottom of the facility. This information is used to verify the infiltration rate or permeability of the soil. For constructed stormwater wetlands, water inflow (base flow and groundwater) must be greater than water losses (infiltration and evaporation). If the infiltration rate of the soil is too great, then a constructed wetland may not be an appropriate BMP, or a liner may be required. The soil permeability may be such that the shallow depths of a constructed wetland can be maintained. However, as the depth of the permanent pool increases, the increased head or pressure on the soil may increase the infiltration rate.

   For discussions regarding the appropriate soils for landscaping, see the Landscape section in this standard and **Minimum Standard 3.05, Landscaping**.

2. **Rock–**

The subsurface investigation should also identify the presence of any rock or bedrock layers. The excavation of rock to achieve the proper wetland dimensions and hydrology may be too expensive or difficult with conventional earth moving equipment. However, blasting may open seams or create cracks in the underlying rock that may result in unwanted drawdown of the permanent pool. Blasting of rock is not recommended unless a liner is used.

3. **Karst–**

In regions where Karst topography is prevalent, projects may require a thorough soils investigation and specialized design and construction techniques. Since the presence of karst may affect BMP selection, design, and cost, a site should be evaluated **during the planning phase of the project**.

4. **Existing Utilities–**

Most utility companies will not allow their underground lines and right-of-ways to be submerged under a permanent pool. If such a site must be used, the designer should obtain permission **before designing the BMP**. Note that if the utilities ever require maintenance or repair, the characteristics of the constructed wetland may be irreparably changed or damaged. The cost to move any existing utilities during initial wetland construction should be determined and included in the project's overall construction costs.

Environmental Impacts

Constructed stormwater wetlands are generally located in areas with favorable hydrology. These locations are prone to being environmentally sensitive (low-lying) as well, and may contain existing wetlands, shallow marshes, perennial streams, wildlife habitat, etc., which may be protected by state or federal laws. The owner or designer should review local wetland maps and contact local, state, and federal permitting agencies to verify the presence of wetlands, their protected status, and the suitability of the location for a constructed wetland.

With careful planning, it may be possible to incorporate wetland mitigation into a constructed stormwater wetland. This assumes that the functional value of the existing or impacted wetland can be identified and included, reconstructed, or mitigated for, in the stormwater wetland. The Virginia Department of Environmental Quality should be contacted for more information regarding wetland mitigation.

Sediment Control

A constructed stormwater wetland should not be used as a sediment control facility during site construction. A presettling basin, or forebay, may be constructed above the proposed constructed wetland facility, however, any planting or preparation of the constructed wetland site should occur after the site construction has been completed. This will eliminate any forseeable impact from sediment loads that overwhelm temporary erosion and sediment control measures during storm events.

Maintenance

Constructed stormwater wetlands require periodic maintenance, as does any stormwater BMP. In addition, a constructed wetland will require active management of the hydrology and vegetation during the first few years or growing seasons in order for it to achieve the performance and functions for which it was designed.

Vehicular access and manuvering room in the vicinity of a constructed wetland (and sediment forebay) is necessary to allow for long-term maintenance. In addition, the establishment of an on-site sediment disposal area, properly located and contained, will significantly reduce the cost of routine maintenance and sediment removal. Care must be taken in the disposal of sediment that may contain an accumulation of heavy metals. **Sediment testing is recommended prior to sediment removal to assure proper disposal**.

## Design Criteria

This section provides minimum criteria and recommendations for the design of a constructed stormwater wetland intended to comply with the runoff quality requirements of the Virginia Stormwater Management program. It is the designer's responsibility to decide which aspects of the program apply to the particular facility being designed and if any additional design elements are required to insure the long-term functioning of the wetland.

Hydrology and Hydraulics

**Chapter 4, Hydrologic Methods** and **Chapter 5, Engineering Calculations** should be used to develop the post-developed hydrology of the wetland's contributing watershed, to analyze the hydraulics of the riser and barrel system (if used) and to design the emergency spillway.

The contributing watershed's area should be a minimum of 10 acres and/or there should be an adequate base flow to support the hydrology.

Embankment

The design of the earthen embankment for any impoundmant BMP should comply with **Minimum Standard 3.01, Earthen Embankment**. Specific requirements for geotechnical analysis, seepage control, maximum slopes, and freeboard are particularly appropriate.

Principal Spillway

The design of the principal spillway and barrel system, or weir overflow system, anti-vortex device, and trash racks should comply with **Minimum Standard 3.02, Principal Spillway**. Weir spillways have a large cross-sectional area that can pass a considerable flow rate at low head conditions. Since reducing the depth of ponding in a constructed wetland helps to avoid stressing plant communities, an armored, weir-type spillway may be the most desirable overflow device for a constructed stormwater wetland. Further, the use of an adjustable weir will help maintain the proper water surface elevation during seasonal extremes.

Emergency Spillway

An emergency spillway that complies with **Minimum Standard 3.03, Vegetated Emergency Spillway** should be provided when possible.

Permanent Pool

Sizing a constructed stormwater wetland is based on maximizing its pollutant removal efficiency. The physical and hydraulic factors that influence the wetland's pollutant removal efficiency are the permanent pool *volume*, *depth*, *surface area*, *geometry*, and *hydraulic residence time*. Minimum design criteria are presented below for each of these factors:

1. **Volume –**

The required permanent pool volume of a constructed stormwater wetland is **2 times the water quality volume** (2 ×WQV). The target pollutant removal efficiency shown in **Table 3.09-1** is based on this sizing criteria.

2. **Depth –**

Four depth zones are needed within the permanent pool of a constructed stormwater wetland: a) *deep pool*, b) *low marsh*, c) *high marsh*, and d) *semi-wet* (see **Figure 3.09-2**).

a. The *deep pool* areas of a constructed wetland should be 18 *inches* to 6 *feet* in depth and may consist of 1) *sediment forebays*, 2) *micro-pools*, and/or 3) *deep-water channels*.

   1. *Sediment forebays* are highly recommended in constructed stormwater wetlands. They should be installed at stormwater inflow points to reduce the velocity of

incoming runoff and trap course sediments, and to spread the runoff evenly over the wetland area. The forebay should be constructed as a separate cell from the rest of the wetland and provide easy access for maintenance with heavy equipment. Refer to **Minimum Standard 3.04, Sediment Forebay** for further information.

2. *Micro-pools* offer open water areas to attract plant and wildlife diversity. If a low-flow discharge pipe is used, it should be constructed on a reverse slope and extended into the wetland below the pool surface elevation but above the bottom elevation. This helps to prevent clogging, since a typical wetland environment consists of floating plant debris and possible sediment and organic accumulation at the bottom. (Refer to the **Overflow** discussion later in this section.)

3. *Deep-water channels* provide an opportunity to lengthen the flow path to avoid seasonal short-circuiting (see pool geometry).

b. The *low-marsh zone* ranges in depth from 6 to 18 inches.

c. The *high-marsh zone* ranges in depth from 0 to 6 inches. Usually, this zone will support the greatest density and diversity of emergent plant species.

d. The *semi-wet zone* refers to the area that, during normal, non-rainfall periods, is above the pool, but is inundated during storm events for a period of time, depending on the amount of rainfall, and the hydraulics of the overflow device.

Note: The low-marsh, high-marsh, and semi-wet zones are useful as a perimeter shelf 10 to 15 feet wide. This shelf, or aquatic bench, can serve as a safety feature to keep children away from the open water deep pool areas. Also, as a secondary benefit, a heavily vegetated perimeter will help to discourage geese from using the facility as a permanent habitat.

The recommended surface area allocation for these depth zones is presented in **Table 3.09-2.**

3. **Surface Area–**

At a minimum, the pool surface area of a constructed stormwater wetland should equal 2% of the size of the contributing watershed. Recommended surface area allocations for different depth zones are shown in **Table 3.09-2** (MWCOG, 1992). Note that if the surface area criteria conflict with the volume allocations, the surface area allocations are more critical to an effective design.

4. **Geometry–**

The geometry of the constructed stormwater wetland must be designed to avoid short-circuiting. Maximum pollutant removal efficiency is achieved with the longest possible flow path, since this increases the contact time over the wetland area. The minimum length-to-width ratio of the pool should be 1:1 in wet weather and 2:1 during dry weather (see **Figure 3.09-3**).

**TABLE 3.09-2**
***Recommended Allocation of Surface Area and Treatment Volume for Various Depth Zones***

| Depth Zone | % of Surface Area | % of Treatment Volume |
|---|---|---|
| *Deep Water*<br>1.5 to 6 feet deep | 10 | 20 |
| *Low Marsh*<br>0.5 to 1.5 feet deep | 40 | * |
| *High Marsh*<br>0 to 0.5 feet deep | 50 | * |
| | | * combined marsh area = 80% of treatment volume |

*Adapted from MWCOG, 1992*

The **wet weather** *length-to-width ratio* is calculated by dividing the straight line distance from the inlet to the outlet by the wetland's average width. The **dry weather** *length-to-width ratio* is calculated by dividing the dry weather flow path length by the wetland's average width. Note that the dry weather flow path is created by constructing high marsh areas perpendicular to the straight line flow path described above. These marsh areas act as submerged berms and lengthen the effective flow path.

5. **Hydraulic Residence Time–**

The hydraulic residence time is the permanent pool volume, divided by the average outflow discharge rate. The longer the residence time, the higher the pollutant removal efficiency (Driscoll, 1983, Kulzer, 1989).

Using *2 × WQV* to size the permanent pool means that smaller storms (*1 × WQV* or *½-in.*) will displace only half of the pool volume of the wetland, thus providing for extended residence times. Larger treatment volumes with respect to the watershed size (*3 × WQV*) will provide longer residence times and, therefore, greater efficiencies. In certain situations, using these larger volumes and efficiencies may be acceptable, but the decision should be made carefully. The associated challenge is to provide the recommended surface area allocations for the different depth zones as previously discussed.

<u>Overflow</u>

Providing flood control and/or channel erosion control within a constructed stormwater wetland creates a hydrologic regime that is very difficult to adapt to in the landscaping plan, due to extreme water depth fluctuations. If a constructed wetland is to serve as a quantity control BMP, it should be designed to provide adequate overflow or bypass for the full range of design storms with as little vertical ponding depth as possible. The hydraulic head needed to pass a design storm is a function of the relationship between the constructed wetland surface area, the geometry of the overflow structure, and the allowable discharge (refer to **Chapter 5, Engineering Calculations**). Outlet structures should be sized to pass the design storms (up to the 10-year storm) with a maximum of 2 feet of water ponded above the wetland pool.

In a stormwater wetland designed for water quality enhancement only, a bypass or diversion structure may be used to prevent sudden surges of runoff from flushing through the wetland (see **Figure 3.09-4**). This establishes the constructed wetland as an off-line facility. If site constraints prevent the use of an off-line facility, then the overflow should be designed to pass the full range of design storms with as little head as possible. An oversized riser and barrel system or a weir structure installed along the berm at the outlet may be used. Refer to **Minimum Standard 3.02, Principal Spillway** for outlet structure design criteria.

Sediment Forebay

Sediment forebays should be installed and designed per **Minimum Standard 3.04, Sediment Forebay**. Generally, they should be constructed at the outfall of incoming storm drain pipes or channels and should be made accessible for maintenance equipment. To lower maintenance costs, an on-site disposal area should be included in the design. Sediment forebays enhance the pollutant removal efficiency of BMPs by containing incoming sediment in one area, which also simplifies monitoring and removal. Therefore, the target pollutant removal efficiency of a constructed stormwater wetland, as presented in **Table 3.09-1**, is predicated on the use of sediment forebays at all inflow points.

Liner to Prevent Infiltration

Constructed stormwater wetlands should have negligible infiltration rates through their bottom. Infiltration impairs the proper functioning of any retention facility by lowering its pool elevation. If infiltration is expected, then a retention BMP must **not** be used, **or** a liner should be installed to prevent infiltration. If a clay liner is used, the specifications provided in **Table 3.09-3** apply and the following are recommended:

1. A clay liner should have a minimum thickness of 12 inches.

2. A layer of compacted topsoil (6 to 12 inches thick, minimum) should be placed over the liner.

3. Other liners may be used if adequate documentation exists to show that the material will provide the required performance.

Safety

The side slopes of a constructed stormwater wetland should be no steeper than 3H:1V. Also, local ordinances may require fencing of deep pool areas next to the shoreline as an additional safety measure. Dense plantings of shoreline fringe vegetation can serve as a safety feature by discouraging access to the pool areas.

**TABLE 3.09 - 3**
***Clay Liner Specifications***

| Property | Test Method (or equal) | Unit | Specification |
|---|---|---|---|
| Permeability | ASTM D-2434 | *cm/sec* | 1 x $10^{-6}$ |
| Clay Plasticity Index | ASTM D-423 & D-424 | % | Not less than 15 |
| Liquid Limit of Clay | ASTM D-2216 | % | Not less than 30 |
| Clay Particles Passing | ASTM D-422 | % | Not less than 30 |
| Clay Compaction | ASTM D-2216 | % | 95% of Standard Proctor Density |

*Source: City of Austin, 1988*

Access

A 10 to 12-foot wide access road with a maximum grade of 12% should be provided to allow vehicular access to the outlet structure area, at least one side of the basin, and the sediment forebay(s). The road's surface should be selected to support the anticipated frequency of use and vehicular load without excessive erosion or damage.

Landscaping

A qualified individual should prepare the landscape plan for a constructed stormwater wetland. Appropriate aquatic, emergent, shoreline fringe, transitional, and floodplain terrace vegetation must be selected to correspond with the expected frequency, duration, and depth of inundation.

The landscaping plan for a constructed wetland is based on the projected depth zones and onsite soil analysis, and should contain the following:

1. **The location, quantity, and propagation methods of plant species and grasses for the stormwater wetland and its buffer.**

The location of plants is based on the depth zones in the wetland and the innundation tolerance of the plant species. Planting zones of uniform depth should be identified for each species selected.

Only one-half of the low- and-high marsh depth zones need to be planted. If the appropriate planting depths are achieved, the entire wetland should be colonized within three years. At least 5 to 7 emergent wetland species, including a minimum of two species for each of the marsh depth zones (high and low), should be used. Selections should be based on wildlife food value, depth tolerance, price, commercial availability and/or shade limitations. Certain species, such as cattails, should be selected with caution. Although they may provide excellent pollutant removal characteristics, they can be invasive and may eventually crowd out other species.

A constructed stormwater wetland does not contain a seed bank, nor does it have an existing natural seed transport cycle as found in native wetlands. While the use of donor soil from disturbed or dredged sites may provide a seed bank, these opportunities may not be readily available. Therefore, the most common and convenient technique for establishing wetland vegetation in a constructed system is to transplant nursery-grown stock. Other propagation techniques (which are outside the scope of this manual) may also prove successful, but special growing conditions must exist.

2. **Instructions for site preparation**.

The soil in which the vegetation is planted should be appropriate for the wetland plants selected. Soil tests showing the adequacy of the soil, or a soil enhancement plan should be submitted with the wetland design.

The soil substrate must be soft enough to permit easy insertion of the plants. If the basin soil is compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked before planting. If soil is imported, it should be laid at least 4 inches deep to provide sufficient depth for plant rooting.

3. **A schedule for transplanting emergent wetland stock**.

The window for transplanting emergent stock extends from early April to mid-June. Dormant rhizomes can be planted in fall or winter. To insure availability, ordering stock 3 to 6 months in advance may be necessary.

4. **Planting procedures**.

A landscape plan should describe any special procedures for planting nursery stock. Most emergent plants may be planted in flooded or dry conditions. If planting is done in dry conditions, then instructions should be included for flooding the wetland immediately following installation.

Proper handling of nursery stock is crucial. The roots must be kept moist to prevent damage. Plants received from the nursery will be in peat pots or bare-rooted. Bare-rooted plants will have some form of protection to keep the roots moist and may be kept for several days, but out of direct sunlight. For the maximum chance of success, all nursery stock should be planted as soon as possible. A minimum acceptable success rate of the plantings should be specified in the plan.

5. **A maintenance and vegetation reinforcement schedule for the first three years after construction**.

Sometimes additional stabilization of the basin area may be necessary to ensure that the vegetation becomes established and mature prior to the erosion of the planting soil. Annual grasses may be used for this purpose. However, the specified application rates in the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition: Temporary Seeding Spec. 3.31 should be reduced to help prevent these grasses from competing with other plants, particularly those emerging from bulbs and rhizomes. Overall, permanent seeding (VESCH Spec. 3.32) should be prohibited in zones 1 through 4, as the grasses will indefinitely compete with the wetland plants. Refer to the Maintenance and Inspection section in this standard for more information.

Additional considerations and criteria for developing a landscape plan can be found in **Minimum Standard 3.05, Landscaping**.

Buffer Zones

A minimum 20-foot wide vegetated buffer, measured from the maximum water surface elevation, should be maintained beside the wetland. Refer to **Minimum Standard 3.05, Landscaping**.

## Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers for embankment ponds and reservoirs, should be followed to build the impoundment.

Further guidance can be found in Chapter 17 of the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to methods and procedures specified for earthwork, concrete, reinforcing steel, pipe water gates, metal work, woodwork and masonry and any other items that apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Guidance and construction specifications in the following minimum standards also apply for various components of the facility: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; and **3.05, Landscaping**.

## Maintenance and Inspections

A constructed stormwater wetland may be maintained without a permit from the U. S. Army Corps of Engineers or the Virginia Department of Environmental Quality (Va. DEQ).

Any pre-treatment facility or diversion structure should be inspected and maintained regularly to remove floatables and any large debris. Sediment should be removed from the forebay every 3 to 5 years, or when 6 to 12 inches have accumulated, whichever comes first. To clean the forebay, draining or pumping and a possible temporary partial drawdown of the pool area may be required. Refer to the VESCH, 1992 edition for proper dewatering methods. A predesignated spoil area, away from the wetlands, should be used.

The constructed stormwater wetland should be inspected at least twice a year in the first three years after construction, during both the growing and non-growing seasons,for vegetative establishment. Inspectors should document plant species distribution and fatality rates and verify compliance with the landscaping specifications. Also, sediment accumulation, water elevations, and the condition of the outlet should be documented. Records should be kept to track the wetland's health over time.

### Management of Wetland Vegetation

The constructed wetland and its buffer may need a *reinforcement planting* at the onset of the second growing season after construction. The size and species of plants to be used should be based on the growth and survival rate of the existing plants at the end of their first growing season. Controlling the growth of certain invasive species, such as cattail and phragmites, may also be necessary. These plants can be very hard to contain if they are allowed to spread unchecked. The best strategy may be to design for a wide range of distinct depth zones.

Research shows that for most aquatic plants the bulk of the pollutants is stored in the roots, not the stems and leaves (Lepp 1981). Therefore, harvesting before winter dieback is unnecessary. Many unanswered questions remain concerning the long-term pollutant storage capacity of plants. Additional plant maintenance recommendations may be presented in the future, as such information becomes available.

The embankment and BMP access road should be mowed biannually, at a maximum, to prevent the growth of trees. Otherwise, the buffer and upland areas should be allowed to grow in meadow conditions.

**FIGURE 3.09 - 1**
***Constructed Stormwater Wetlands - Plan***

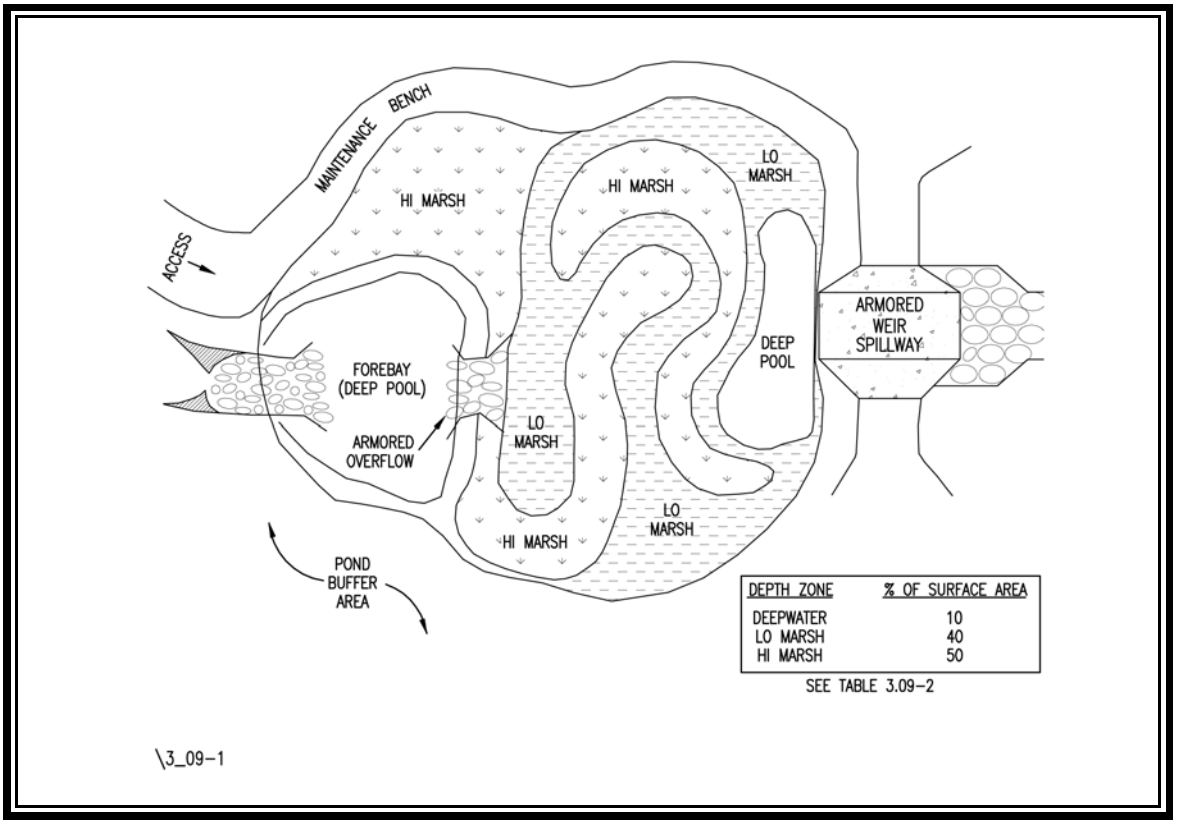



**FIGURE 3.09 - 2**
***Constructed Stormwater Wetlands - Depth Zones***

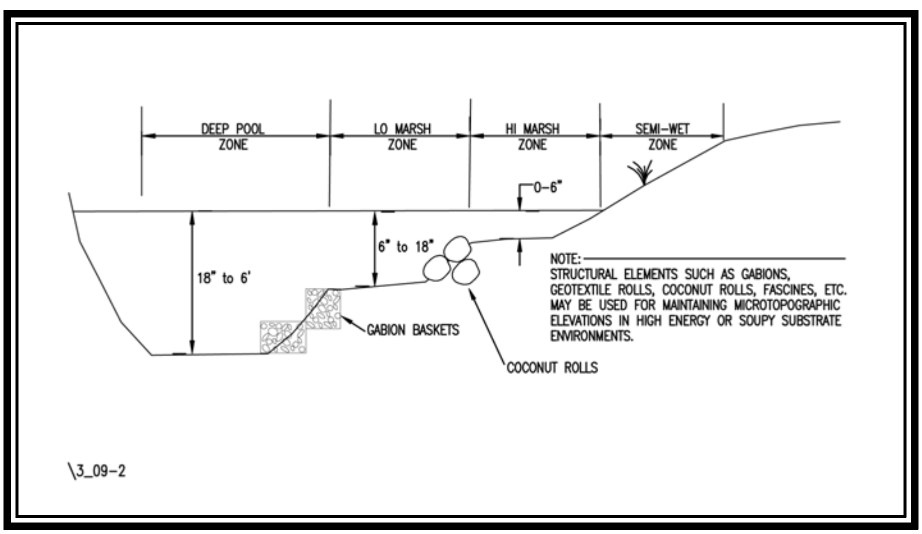


**FIGURE 3.09 - 3**
***Dry Weather and Wet Weather Flow Paths***

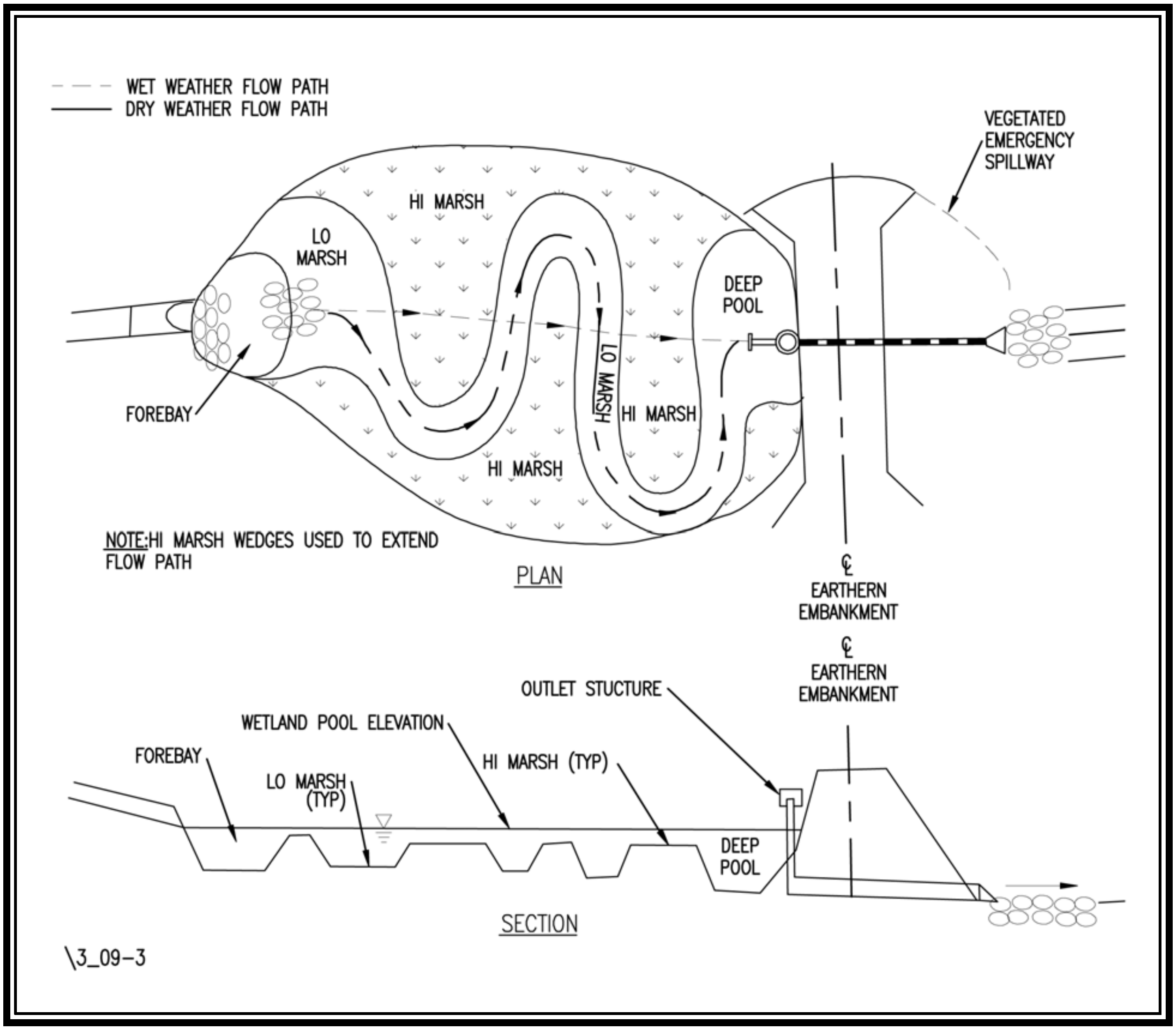
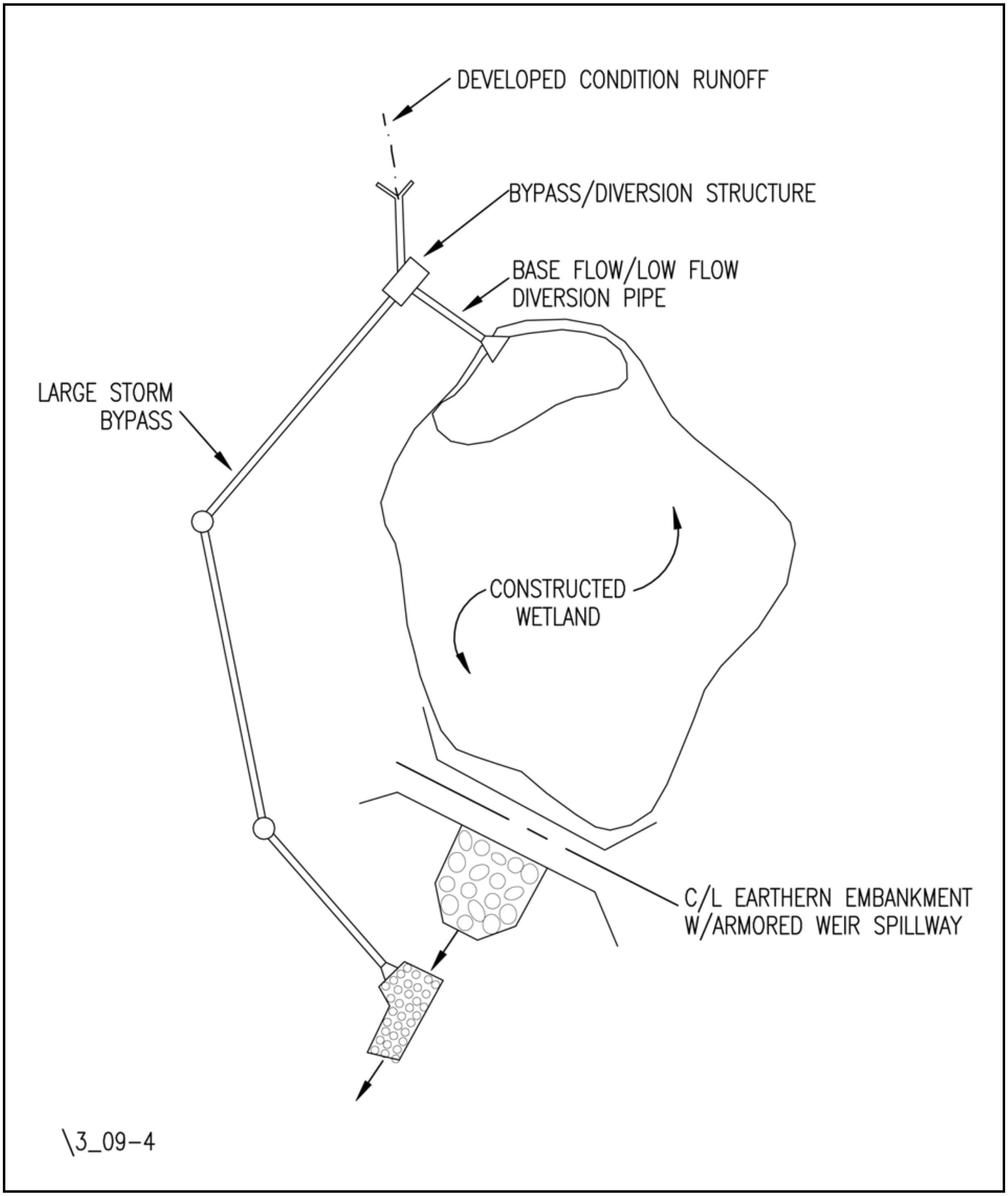


**FIGURE 3.09 - 4**
***Off-line Bypass Structure***



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Constructed Stormwater Wetland – recently completed.

Constructed Stormwater Wetland – becoming stabilized, emergent vegetation barely visible.

# Constructed Stormwater Wetland

Constructed Stormwater Wetland. Note vegetation protected from waterfowl by netting system.

Forebay and Constructed Stormwater Wetland incorporated into regional retention basin design.

# Constructed Stormwater Wetland

## *MINIMUM STANDARD 3.10*

# GENERAL INFILTRATION PRACTICES

| | |
|---|---|
| 3.10A | Infiltration Basin |
| 3.10B | Infiltration Trench |
| 3.10C | Roof Downspout System |
| 3.10D | Porous Pavement |

View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.10

# GENERAL INFILTRATION PRACTICES

### Definition

Infiltration facilities temporarily impound stormwater runoff and discharge it via infiltration into the surrounding soil.

### Purpose

Infiltration facilities are primarily used for water quality enhancement. Their use to control large volumes of runoff for flooding and channel erosion control is often impractical. Therefore, the infiltration facilities presented in this handbook should generally be used to control the water quality volume and up to the 2-year design storm only. Infiltration practices that capture all of the runoff from the "first flush" (i.e., the water quality volume) may utilize dry storage above the water quality volume to provide sufficient reductions in the 1- or 2-year peak discharge as required. The 10-year and 100-year flows will usually exceed the capacity of an infiltration facility. **Table 3.10-1** contains the target pollutant removal efficiencies based on the runoff volume to be controlled.

Infiltration practices are appealing in that they help to reverse the hydrologic consequences of urban development by reducing peak discharge and providing groundwater recharge.

**TABLE 3.10 - 1**
***Pollutant Removal Efficiency for Infiltration Facilities***

| BMP Description | Target Phosphorus Removal Efficiency |
|---|---|
| Infiltration facility with storage volume equivalent to 0.5 inches of runoff from the impervious Area. | 50% |
| Infiltration facility with storage volume equivalent to 1.0 inch of runoff from the impervious area. | 65% |

**FIGURE 3.10 - 1a**
*Infiltration Basin - Plan and Section*

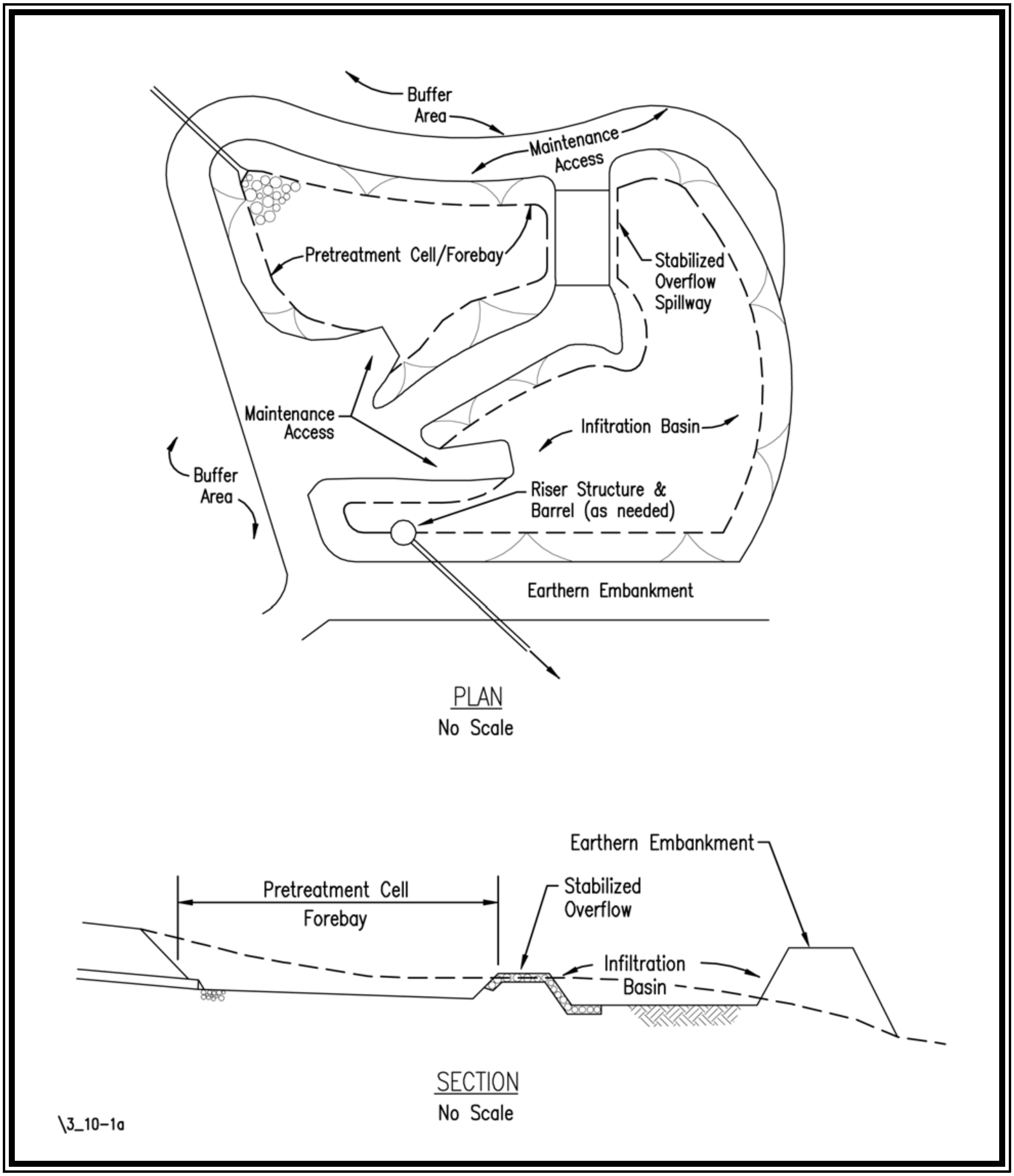
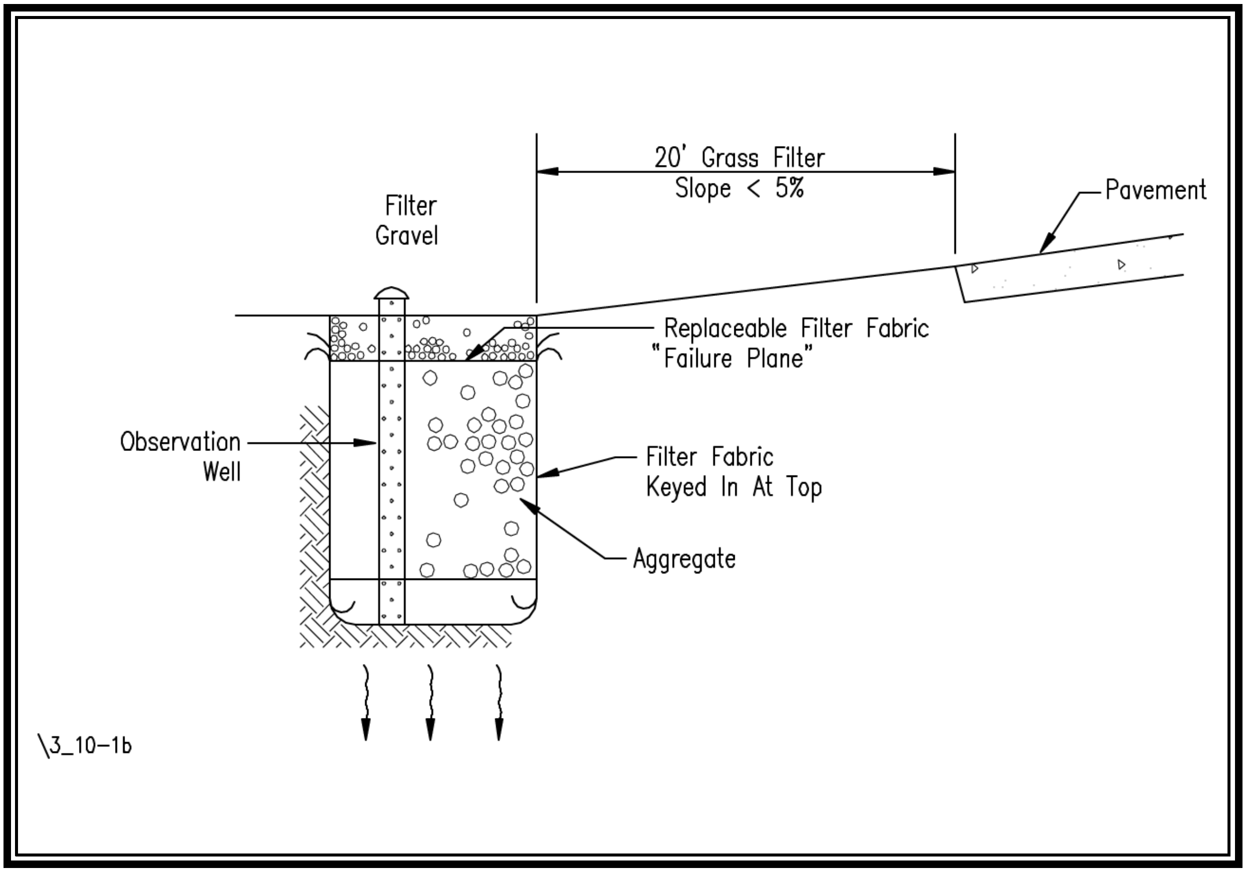


**FIGURE 3.10 - 1b**
*Infiltration Trench - Section*




## Conditions Where Practice Applies

Infiltration facilities are suitable for use where the subsoil is sufficiently permeable to provide a reasonable rate of infiltration. They are also practical where the water table is sufficiently lower than the design depth of the facility to prevent pollution of the groundwater. Infiltration is not recomended for areas underlain by karst topography. Concentrating runoff into an infiltration facility may cause solution channels to develop or cause karst collapse.

Infiltration practices are generally suited for low- to medium-density development (38% to 66% impervious cover). Specific conditions such as drainage area size and development conditions for each infiltration practice are discussed in the appropriate section of this Standard.

Infiltration facilities are subject to clogging and, therefore, are not recommended for areas where sediment, grease, or oil loadings may be high. Such areas include roadways, parking lots, car service facilities, etc. To increase the life expectancy of an infiltration facility, a pretreatment facility such as a settling basin or "cell", or additional BMP in series should be used to remove sediments or other substances from the stormwater runoff **before** it enters the infiltration facility. Refer to **Minimum Standard 3.15, Manufactured BMP Systems** for additional pretreatment BMPs.

## Planning Considerations

The following planning considerations are provided for infiltration practices overall. More specific considerations that may be applicable are presented with each infiltration practice.

Site Conditions

In the past, many designs were accepted based on soils information compiled from available data, such as SCS soil surveys. While these sources may be appropriate for a pre-engineering feasibility study, final design and acceptance should be based on an actual subsurface analysis and permeability tests.

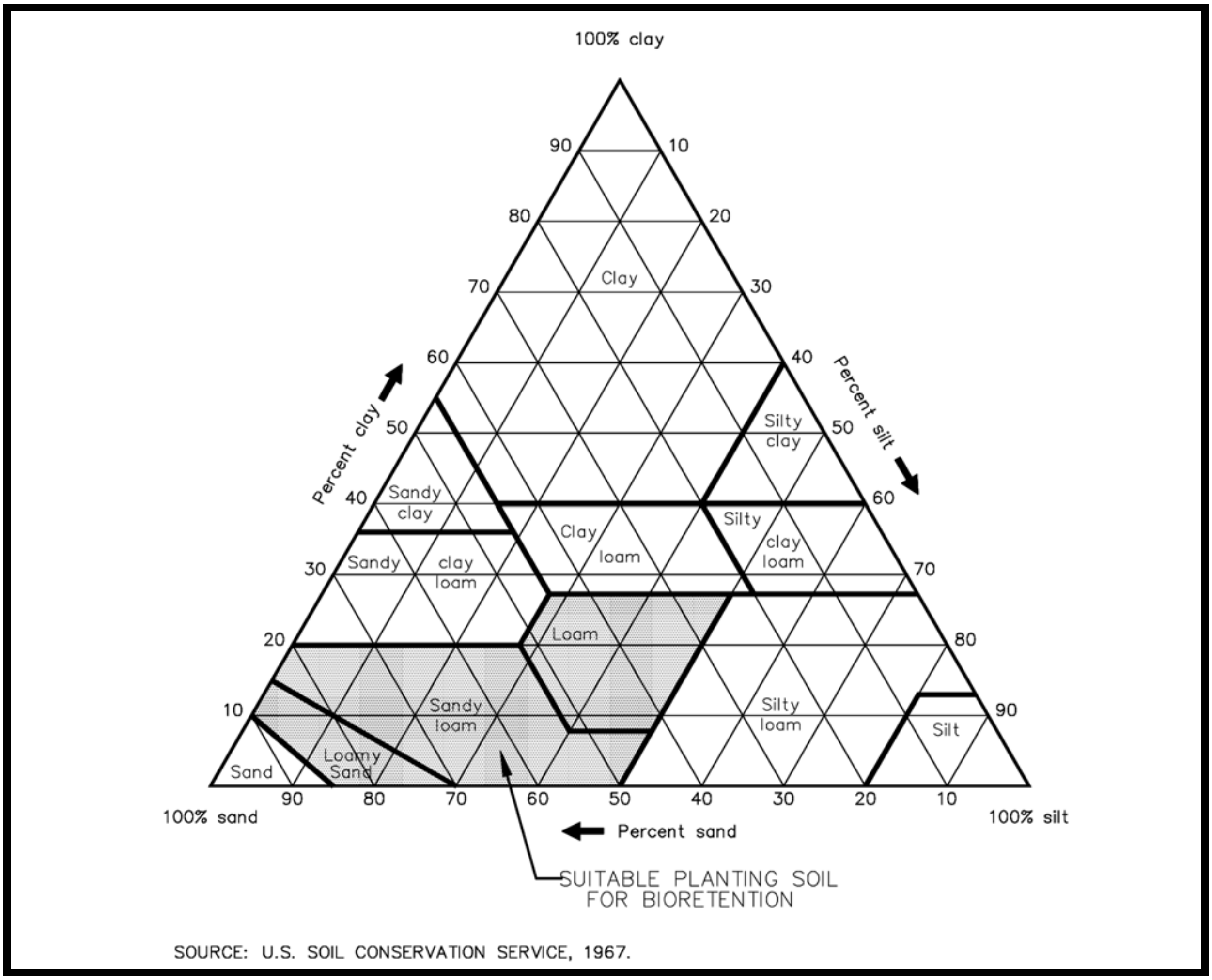
The high failure rates of infiltration facilities, as presented in recent studies (MWCOG), suggest that site-specific soil borings should be required to support the use of infiltration practices. The suitability of the soil for use with the desired infiltration practice can be determined from the soil boring analysis. Details for appropriate geotechnical techniques can be found in the references listed at the end of this section (MD WRA). In general, the following information should be included in a site-specific subsurface or geotechnical study:

1. **Soil permeability**

   The soil types within the subsoil profile, extending a minimum of 3 feet below the bottom of the facility, should be identified to verify the ***infiltration rate*** or ***permeability*** of the soil. The infiltration rate, or permeability, measured in inches per hour, is the rate at which water passes through the soil profile during saturated conditions. Minimum and maximum infiltration rates establish the suitability of various soil textural classes for infiltration. Each soil texture and corresponding hydrologic properties within the soil profile are identified through analysis of a gradation test of the soil boring material. **Soil textures acceptable for use with infiltration systems include those with infiltration rates between 0.52 inches per hour and 8.27inches per hour, and include loam, sandy loam, and loamy sand**.

*Soil textures with infiltration rates* ***less than 0.52 inches per hour*** *or greater than* ***8.27 inches per hour*** *are* ***not suitable*** *for infiltration practices.*

**FIGURE 3.10 - 2**
***USDA Textural Triangle***




Soils that have a 30% clay content are unacceptable for use with infiltration facilities since they are structurally unstable and susceptible to frost heaving. Similarly, soils that have poor percolation capabilities or excessively drained soils, such as sand, should not be used for infiltration purposes. The soil textures presented in **Table 3.10-2** correspond to the soil textures of the U.S. Department of Agriculture (USDA) Textural Triangle presented in **Figure 3.10-2**. It should be noted that the difference in soil textures of sand and loamy sand are the percentages of clay found in the soil. While the actual percent of difference is small, a significant difference in infiltration rates can be expected. Note that actual permeability tests may indicate infiltration rates different from those in **Table 3.10-2**.

Predicting the exfiltration of water from an infiltration facility is difficult, especially over an extended period, such as the desired life expectancy of the facility. A factor of safety should be applied in the design to ensure that the facility is sized to function even when partially clogged. (This is discussed further in the **General Design Criteria** presented later in this section.)

**TABLE 3.10 - 2**
***Hydrologic Soil Properties Classified by Soil Texture***

| Texture Class | Effective Water Capacity ($C_w$) (inch per inch) | Minimum Infiltration Rate (*f*) (inch per hour) | Hydrologic Soil Grouping |
|---|---|---|---|
| Sand | 0.35 | 8.27 | A |
| Loamy Sand | 0.31 | 2.41 | A |
| Sandy Loam | 0.25 | 1.02 | B |
| Loam | 0.19 | 0.52 | B |
| Silt Loam | 0.17 | 0.27 | C |
| Sandy Clay Loam | 0.14 | 0.17 | C |
| Clay Loam | 0.14 | 0.09 | D |
| Silty Clay Loam | 0.11 | 0.06 | D |
| Sandy Clay | 0.09 | 0.05 | D |
| Silty Clay | 0.09 | 0.04 | D |
| Clay | 0.08 | 0.02 | D |

2. **Depth to the seasonal high groundwater table and bedrock**.

   Typically, infiltration facilities are not recommended in areas with a high groundwater table due to the inability of the soil to adequately filter out pollutants before the stormwater enters the water table. A distance of **2** to **4** feet is required between the bottom of an infiltration facility and the existing water table or bedrock. Similarly, infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

Determination of the seasonal high groundwater table elevation should be given a high priority because flooding of an infiltration facility will render it inoperable during periods of high precipitation. Occasionally, based on the hydraulic conductivity of the soil and the physical dimensions of the trench, a greater separation than 2 to 4 feet may be necessary. Since some soils do not always contain the low chroma (gray) mottles indicative of seasonal saturation, an observation well may be used to locate the seasonal high groundwater table to verify the soil analysis.

Subsurface analysis techniques and related engineering recommendations are too broad and complex for the scope of this handbook. The references listed at the end of this section are recommended for further reading if more detailed information regarding the feasibility analysis of subsurface conditions is needed.

Selecting the optimum depth of an infiltration facility is a process of analyzing constraints. It includes seeking those soil horizons which have a permeability rate that will allow the structure to empty within 48 hours after a design storm event. The design elements of this process are covered in **General Design Criteria**, presented later in this section.

3. **Topographic conditions**

The topographic conditions of a development site represent feasibility factors that should be examined before designing an infiltration system. These factors include the slope of the land, the nature of the soil (natural or fill), and the proximity of building foundations and water supply wells.

The use of a particular BMP is restricted by the allowable slope for that practice. Porous asphalt pavement, for example, requires a relatively level or gently sloping area less than or equal to 3% (20H:1V). All other infiltration practices should be located in areas in which the slope does not exceed 20% (5H:1V). Using infiltration practices on a steep grade increases the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount which infiltrates.

Developments occurring on sloping and rolling sites often require extensive cut and fill operations. The use of stormwater management infiltration systems on fill material is not recommended due to the possibility of creating an unstable subgrade. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be aggravated if the fill material is allowed to become saturated by using infiltration practices.

Nearby building foundations should be at least 10 feet up-gradient of the infiltration system to prevent the possibility of flooding basements. Proximity to septic systems is also a concern and local health officials should be consulted for guidance on minimum setbacks. Additionally, the location of infiltration practices should be a minimum of 100 feet from any water supply well where the runoff is from commercial or industrial impervious parking areas.

Sediment Control

It has been reported that many infiltration BMPs have failed because adequate precautions to prevent sediment contamination were not implemented (NVPDC, MWCOG). Provisions for long-term sediment control, or pretreatment of the stormwater runoff, must be incorporated into the design, along with precautions taken during onsite construction activities. Advance consideration should be given to the potential impacts that construction techniques, work sequence, and equipment could have on the future maintenance requirements of the BMP. Serious maintenance problems can be averted, or reduced, by the adoption of relatively simple measures during construction.

1. **Construction Runoff**

***Infiltration BMPs should be constructed AFTER the site work is completed and stabilization measures have been implemented.***

Infiltration facilities built prior to the completion of site construction activities often become choked with sediment, rendering them inoperable from the outset. Simply providing inlet protection or some other filtering mechanism during site construction may not adequately control the sediment. One large storm can overload protection devices and completely clog the infiltration facility.

To protect an infiltration facility **during** construction, provisions for sediment control should be included in the design. The following references provide technical guidance on sediment control designs:

¢ Virginia Erosion and Sediment Control Handbook (VESCH), DCR, 1992,
¢ Standards and Specifications for Infiltration Practices, Md. DNR, 1984, and
¢ Controlling Urban Runoff (MWCOG, 1987).

***Experience with infiltration practices in other states has shown that stormwater management infiltration facilities must be protected until their contributing drainage areas have been adequately stabilized*** *(Maryland,1987).*

The definition of the term "adequately stabilized" when describing the contributing drainage area of an infiltration BMP is critical to the success of the facility. An approved erosion and sediment control plan will specify various devices for trapping sediment during construction, such as silt fences, diversions, sediment traps, etc. It will also specify measures and provide specifications for site stabilization. Following construction activities, the temporary sediment control measures should be removed at the direction of the erosion control inspector when, at a minimum, stabilization measures, such as seed and mulch, are in place. This does not mean, however, that stabilization has occurred. Often, it may take one or more full growing seasons before the pervious areas are fully stabilized, and the construction-related sediment load is controlled. **Therefore, provisions to bypass the stormwater around, or away from, the infiltration facility during the stabilization period should be implemented.**

2. **Urban Runoff**

A fully stabilized site will generate a particulate pollutant load resulting from natural erosion, lawn and garden debris such as leaves, grass clippings, mulch, roadway sand, etc. Various measures can be incorporated into the design to protect the facility and facilitate regular maintenance. The following discussion on pretreatment systems for infiltration facilities is adapted from the Northern Virginia BMP Handbook (NVPDC 1992) and Standards and Specifications for Infiltration Practices (Md. DNR, 1984).

Urban and ultra-urban development projects are usually limited to the use of infiltration trenches, which include ***dry wells***, ***porous pavement***, and ***roof downspout systems***. Runoff to any infiltration trench must be filtered to remove sediment prior to entering the structure.

Runoff to an infiltration trench is usually ***concentrated input***, which is conveyed by gutters, inlets, or pipes, and enters the facility at one or more points. Sediment control devices for *concentrated input* include in-line structures such as water quality inlets (Refer to **Minimum Standard 3.15, Manufactured BMP Systems**), sediment collection sumps or similar structures, provided there is an assured means of regular inspection and maintenance. Any pretreatment BMP which allows sediment- laden water to enter the infiltration facility upon failure of the pretreatment BMP should be avoided. Ideally, a clogged or failed pretreatment BMP should create a noticeable amount of overland flow bypassing the infiltration facility, which indicates that it is time to maintain the pretreatment decvice. Prompt maintenance of the pretreatment BMP will ensure that the infiltration facility remains intact.

The design of sediment control systems for concentrated input facilities invites innovation. Redundant controls or backup systems should be employed wherever there is an opportunity. One type of backup sediment control measure used for trenches with large diameter CMP pipe storage consists of lining the interior surface of the pipe with a geotextile fabric as shown in **Figure 3.10-3**. This continuous liner is held against the interior metal surface of the pipe by expandable rings. If routine monitoring reveals that the water is not being released from the pipe, the filter should be inspected and replaced as necessary. Note that the diameter of the pipe must be such that access for maintenance is possible.

**Any sediment collection structure must be adequate to handle the expected flows**. Therefore, filter systems should be designed with an additional capacity to account for eventual, partial clogging.

Runoff to an infiltration BMP may also be in the form of ***sheet flow***, entering the top of the storage reservoir over a wide area. **Figure 3.10-1b** portrays one such infiltration trench where overland sheet flow is directed across a gently sloping grassed filter strip to the surface of the infiltration trench. The grassed filter strip is the primary pretreatment control and must be at least **20 feet wide** and have a **5% slope or less** to be effective. The entry berm must be parallel to the contour to maintain uniform flow to the trench.

The choice of vegetative cover should be made with respect to its tolerance to water, growth rate, climatic preference, stabilization capacity, and maintenance considerations. Refer to the VESCH DCR, 1992, and any local ordinances for specific vegetative recommendations. It is essential that a complete cover of dense turf be established **BEFORE** stormwater flows are allowed to enter the facility.

The trench itself is protected from sediment entry by a layer of geotextile filter fabric (called a *sediment barrier*). The sediment barrier is separate from the filter fabric which lines the trench sides so it can be replaced as part of routine maintenance. It is installed over the top of the crushed stone storage chamber and covered with one-half to one foot of 3/4-inch crushed stone. The edges of the filter fabric must be placed so that runoff cannot bypass the sediment barrier. All input water must flow over the grassed filter strip and enter the trench through the sediment barrier at the top.

Unlike the other trench types, porous pavement may be difficult to maintain because the pollutant load is carried by other means, such as vehicle traffic, rather than runoff. Porous pavement, therefore, requires a strict maintenance program to ensure that the design flow can pass through the pavement. Specific maintenance requirements, along with construction methods and specifications for porous pavement and various other infiltration BMPs, are provided later in this chapter.

**FIGURE 3.10 - 3**
*Concentrated Input Pretreatment*

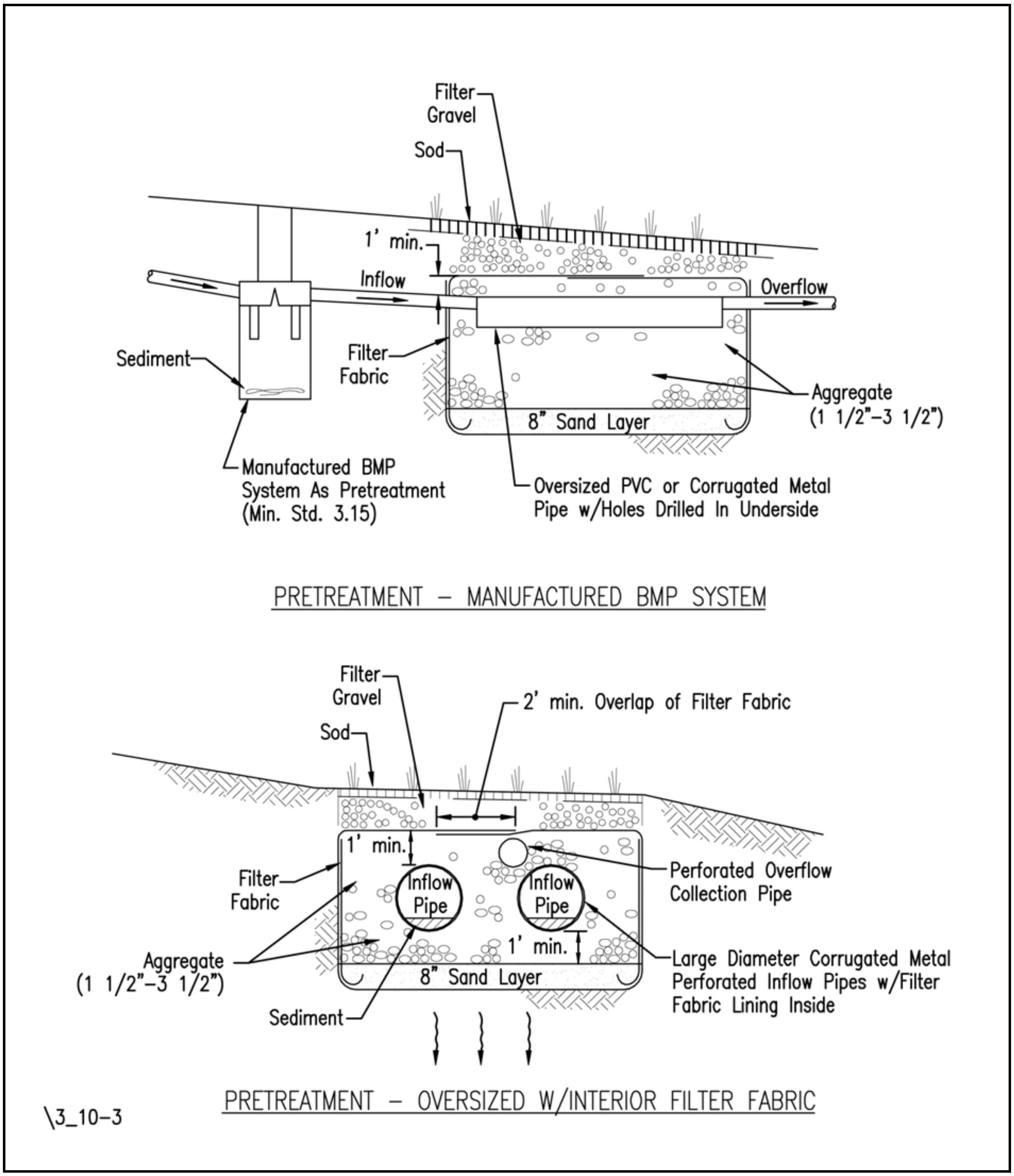
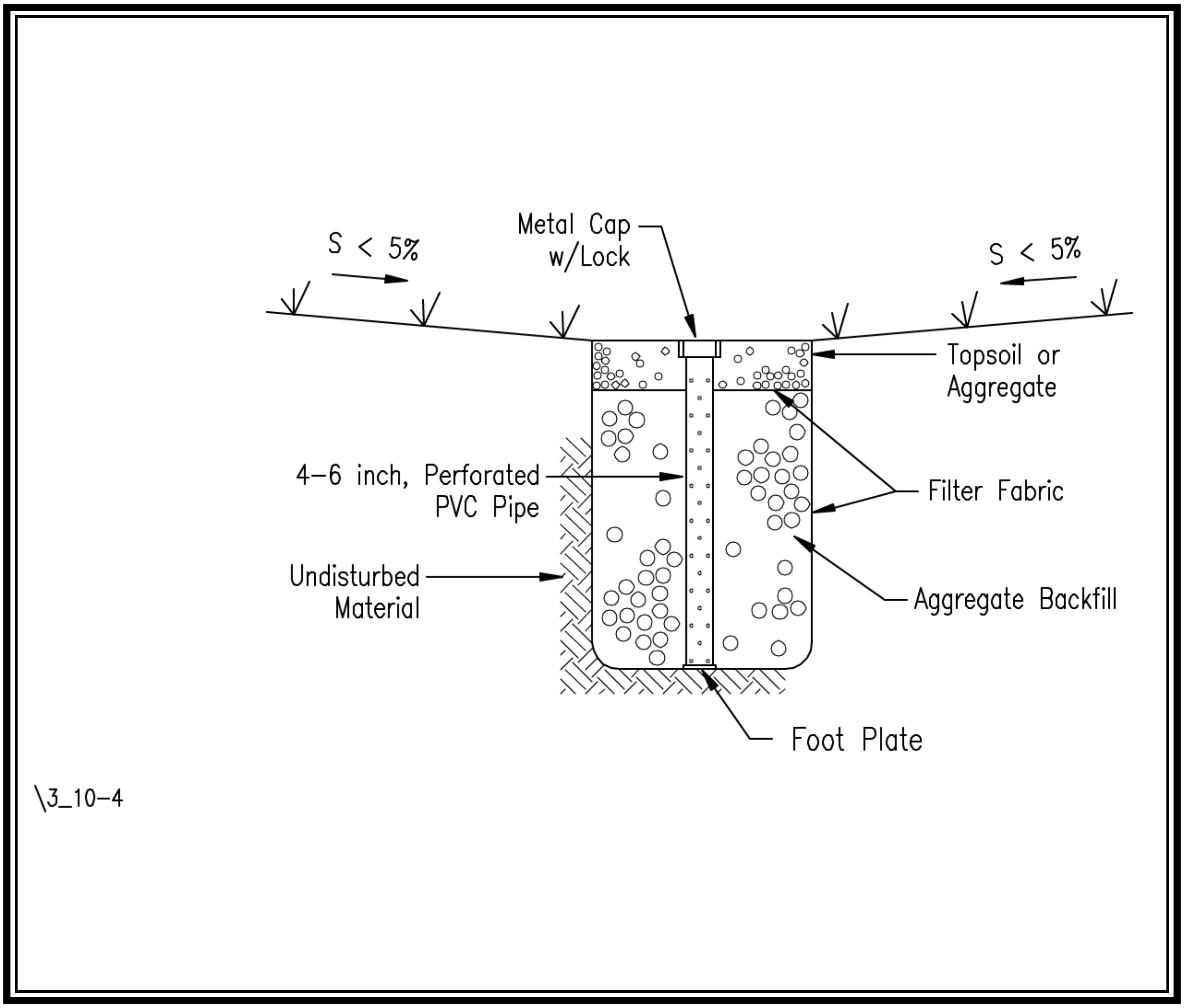


**FIGURE 3.10 - 4**
***Observation Well***




Maintenance

The maintenance requirements for a selected infiltration practice must be considered during the planning and design of the facility. Surface facilities such as basins and swales can be visually inspected and easily maintained. The surface of an infiltration trench or dry well can also be visually inspected and maintained if they are constructed at grade. Since their subsurface storage areas cannot be inspected above ground, **observation wells must be required** (refer to **Figure 3.10-4**). Maintenance of the subsurface storage area, however, short of excavating the facility, is very difficult. Therefore, many landowners, developers and local program administrators have been discouraged from using infiltration facilities.

Recent studies indicated that slightly more than half of the surveyed infiltration facilities had failed within the first five years of operation (MWCOG, 1992; Md. DOE, 1987). Often, failure was due to poor subsurface investigations and/or sediment control. Since repair or rehabilitation of underground facilities (infiltration trenches) is limited, design criteria, subsurface exploration, and maintenance requirements should be strictly enforced. In addition, pretreatment of the stormwater runoff will likely extend the life of an infiltration facility by trapping sediments and debris before they enter, and by allowing for the removal of the accumulated material without excavating the structure. To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the stone reservoir portion of infiltration trenches be located in a lawn area and as close to the ground surface as possible.

***Infiltration trenches should not be located beneath paved surfaces, such as parking lots.***

## General Design

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration practices intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

The types of infiltration facilities which are recognized for stormwater management purposes are ***infiltration basins*** and ***infiltration trenches***. The design, construction, and maintenance criteria for infiltration trenches is also applied to the design of the storage volume for ***porous pavement*** and ***roof downspout systems*** (or *dry wells*).

The criteria presented below apply to the design of infiltration basins and trenches for ***water quality enhancement***. This means that the runoff volume to be treated is determined by the water quality volume and the desired pollutant removal efficiency.

Hydrology and Hydraulics

The procedures outlined in **Chapter 4, Hydrologic Methods**, should be used to determine the post-developed hydrology of the drainage area being served by the infiltration BMP. Provisions for large storm bypass must be provided, even when a stormwater BMP is being utilized for water quality enhancement only and not peak discharge control. Ideally, large storms should be diverted around infiltration facilities, or through the facility with a minimum of disruption and/or turbulence

Sizing Procedure

The storage volume required for infiltration facilities designed for water quality enhancement is determined by the water quality volume - ½ to 1 inch of runoff, determined by the desired pollutant removal efficiency (refer to **Table 3.10-1**).

A Darcy's Law approach is recommended for sizing water quality infiltration BMPs. This will assume that the drain time of the facility is controlled by one-dimensional flow through the bottom surface.

$$Q = f\, I\, SA$$

**Equation 3.10-1**
**Darcy's Law**

where:
- $Q$ = rate of exfiltration into soil, cfs
- $f$ = infiltration rate of the soil in ft/hr
- $I$ = hydraulic gradient
- $SA$ = bottom surface area of facility in $ft^2$

1. **Infiltration Rate** –

Over the life of an infiltration facility, the rate of infiltration into the soil, $f$, may gradually decrease due to clogging of the surface layer of soil. The documented high failure rate of infiltration facilities (MWCOG) suggests that a safety factor be built into the design of the facility to allow for future clogging. Therefore, ***a safety factor of 2*** should be applied to the infiltration rate determined from the soil analysis. The design soil infiltration rate, $f_d$, therefore, is equal to one-half of the actual rate:

$$f_d = 0.5f$$

2. **Hydraulic Gradient –**

In areas with a shallow water table or impermeable layer, the hydraulic gradient may have an impact on the allowable design depth. The hydraulic gradient is given by the equation:

$$I = \frac{h + L}{L}$$

**Equation 3.10-2**
**Hydraulic Gradient**

where: $I$ = hydraulic gradient

$h$ = height of the water column over the infiltrating surface, ft.
$L$ = distance from the top surface of the BMP to the water table, bedrock, impermeable layer, or other soil layer of a different infiltration rate, ft.

**The hydraulic gradient will be asummed to be equal to one in all infiltration designs since the gradient approaches unity as the facility drains. Therefore,**

$$I=1$$

3. **Maximum Ponding or Storage Time, $T_{max}$ –**

A water quality infiltration facility should be designed with a maximum drain time, $T_{max}$, of 48 hours for the total volume.

The maximum drain time, along with the minimum design soil infiltration rate, $f_d$, as verified through a subsurface investigation and analysis, will dictate the maximum allowable design depth, $d_{max}$, of the structure. The maximum depth for an infiltration basin and trench is covered in the following minimum standards.

## MINIMUM STANDARD 3.10A

# INFILTRATION BASIN

### Definition

An infiltration basin is a vegetated, open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata.

### Purpose

Infiltration basins are used primarily for water quality enhancement. However, flooding and channel erosion control may also be achieved within an infiltration basin by utilizing a multi-stage riser and barrel spillway to provide controlled release of the required design storms above the water quality (infiltration) volume (refer to **Figure 3.10-1**).

### Conditions Where Practice Applies

Infiltration basins may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.

Drainage Area

Drainage areas served by infiltration basins should be limited to less than 50 acres. Drainage areas which are greater than 50 acres typically generate such large volumes of runoff that other detention or retention BMPs are more practical and cost-effective.

Development Conditions

Infiltration basins are generally suitable BMPs in low- to medium-density residential and commercial developments (38% to 66% impervious cover).

## Planning Considerations

Appropriate soil conditions and protection of the groundwater are among the important considerations when planning an infiltration basin. Refer to the **Planning Considerations** for **General Infiltration Practices** previously discussed in this standard.

An infiltration basin has relatively large surface area requirements, when compared with an infiltration trench or dry well, and ranges from 3 to 12 feet in depth. The seasonal high groundwater table or bedrock should be located at least 2 to 4 feet below the bottom of the basin. Infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

### Maintenance

Like all stormwater BMPs, access to an infiltration basin should be considered in the planning stage. Access (as well as maneuvering room) should be provided to at least one side of the facility and the control structure or spillway. In addition, identifying a location and designing for on-site sediment disposal will greatly reduce long-term maintenance costs.

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration basins intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

### General

The design of infiltration basins should be according to the following Minimum Standards where applicable: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; **3.05, Landscaping**, and **3.10, General Infiltration Practices**, along with additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for his or her particular design but also for ensuring their long-term operation by specifying appropriate structural materials.

The design of the overflow vegetated spillway must consider the frequency of flow. The spillway may require an armored bottom if it is to function during every storm which exceeds the water quality volume (refer to **Minimum Standard 3.03**).

Hydrology and Hydraulics

**Chapter 4**, **Hydrologic Methods** should be used to develop the pre- and post-developed hydrology for a basin's contributing watershed. An infiltration basin designed for water quality enhancement still must provide an overflow or spillway for the bypass of large storms. **Chapter 5**, **Engineering Calculations** provides the procedures for the design of the riser and barrel system and the emergency spillway design procedures.

Soils Investigation

A minimum of one soil boring log should be required for each 5,000 square feet of infiltration basin area (plan view area) and under no circumstances should there be less than three soil boring logs per basin (Washington State DOE, 1992). Refer also to the **Planning Considerations** and **Design Criteria** of **General Infiltration Practices**, discussed at the beginning of this standard.

Topographic Conditions

Infiltration basins should be a minimum of 50 feet from any slope greater than 15%. If unavoidable, a geotechnical report should address the potential impact of infiltration on or near the steep slope. Developments on sloping sites often require extensive cut and fill operations. **The use of infiltration basins on fill sites is not permitted**. Also, infiltration basins should be a minimum of 100 feet up-slope and 20 feet down-slope from any buildings.

Design Infiltration Rate

The design infiltration rate, $f_d$, should be set to equal one-half the infiltration rate, $f$, determined from the soil analysis. Therefore:

$$f_d = 0.5\,f$$

Maximum Ponding Time and Depth

All infiltration basins should be designed to completely drain stored runoff within 2 days following the occurrence of a storm event. Thus, an allowable maximum ponding time, $T_{max}$ , of 48 hours should be used.The maximum ponding depth for an infiltration **basin** is:

$$d_{max} = f_d T_{max}$$

**Equation 3.10-3**
**Maximum Ponding Depth for Infiltration Basin**

where: $d_{max}$ = maximum depth of the facility, in ft.
$f_d$ = design infiltration rate of the basin area soils, in ft/hr ($f_d$ = ½ $f$)
$T_{max}$ = maximum allowable drain time = 48 hrs.

The ponding depth should not be so great as to contribute to the compaction of the soil surface. Depending on the specific soil characteristics, a maximum ponding depth of 2 feet is generally recommended (MWCOG, 1992).

The minimum surface area of the facility bottom is:

$$SA_{min} = \frac{Vol_{wq}}{f_d T_{max}}$$

**Equation 3.10-4**
**Minimum Bottom Surface Area for infiltration Basin**

where: $SA_{min}$ = minimum basin bottom surface area, in $ft^2$;
$Vol_{wq}$ = water quality volume requirements, in $ft^3$;
$f_d$ = design infiltration rate of the basin area soils, in ft/hr;
$T_{max}$ = maximum allowable drain time, in hours

Runoff Pretreatment

Infiltration basins should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the infiltration basin. Vegetated filters, sediment traps and/or forebays, water quality inlets (refer to **Minimum Standard 3.15, Manufactured BMP Systems**) are just a few of the available pretreatment strategies. Refer to the discussion on **Sediment Control** in the **General Infiltration Practices** portion of this section.

At a minimum, the layout and design of the basin should include a sediment forebay or pretreatment cell, as shown in **Figure 3.10-1**, to enhance and prolong the infiltration capacity. Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements. It is recommended that a grass strip or other vegetated buffer at least 20 feet wide be maintained around the basin to filter surface runoff.

Principal and Emergency Spillways

A diversion structure upstream of an ***off-line*** basin will regulate the rate of flow into the basin, but not the volume. Therefore, infiltration basins should have a spillway to convey flows from storm events which are larger than the design capacity. The primary outlet should be located above the required infiltration volume. Additionally, a riser and barrel system is advantageous for future conversion to an extended-detention or retention facility if the infiltration capacity of the soil becomes impaired. All design elements of a principal spillway should be per **Minimum Standard 3.02, Principal Spillways**.

An emergency spillway is recommended for all impounding structures, including infiltration basins. If a vegetated spillway is to be used as the primary outlet above the water quality volume, care should be taken to design for the increased frequency of use. This is especially critical between maintenance operations when the infiltration capacity is decreased due to sediment loads. If a spillway is to be used for all storms which generate more runoff than the water quality volume, then a nonerodible surface should be provided. All design elements of a *vegetated* emergency spillway should be per **Minimum Standard 3.03, Vegetated Emergency Spillways**.

Stabilization

As with all stormwater structures, all disturbed areas associated with the construction of the facility, including spoil and borrow areas, should be stabilized immediately according to the VESCH 1992 edition. The basin floor area, emergency spillway, and any vegetative buffer around the facility are critical areas and should be addressed with a specific stabilization measure.

The choice of vegetative cover should be made with respect to its tolerance to water, growth rate, climatic preference, stabilization capacity, and maintenance requirtements. Refer to the VESCH 1992 edition and any local ordinances for specific vegetative recommendations. It is essential that a complete cover of dense turf be established **BEFORE** stormwater flows are allowed to enter the facility.

Fencing

Fencing may be provided where deemed necessary by the developer, land owner, or locality for the purposes of public safety or protection of vegetation.

## Construction Specifications

In general, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government.

The construction of infiltration basins should also be in accordance with the following Minimum Standards and Specifications where applicable: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebays**; **3.05, Landscaping**; along with the criteria set forth below. These specifications have been adapted from Standards & Specifications for Infiltration Practices (Md. DNR, 1984 and Washington State DOE, 1992).

### Sequence of Construction

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. Rough excavation of the basin may be scheduled with the rough grading phase of the project to permit use of the material as fill in earthwork areas. Otherwise, **infiltration measures should not be constructed or placed into service until the entire contributing drainage area has been stabilized**. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed basin with a large volume of fine sediment. This could seriously impair the natural infiltration ability of the basin floor.

The specifications for construction of a basin should state the following: 1) *the earliest point at which storm drainage may be directed to the basin*, and 2) *the means by which this delay in basin use is to be accomplished*. Due to the wide variety of conditions encountered among projects, each project should be evaluated separately to postpone basin use for as long as possible.

### Excavation

Initially, the basin floor should be excavated to within one foot of its final elevation. Excavation to the finished grade should be delayed until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light, tracked-equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Lining Material

Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates. Inflow points to the basin should also be protected with erosion controls (e.g., riprap, flow spreaders, energy dissipators, etc.), as well as a sediment forebay.

Selection of suitable vegetative materials and application of required fertilizer and mulch should be per the VESCH 1992 edition.

## Maintenance / Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

When infiltration basins are first made functional they should be inspected monthly and after any large storm event. Thereafter, once the basin is functioning satisfactorily and without potential sediment problems, inspections may be made semi-annually and after any large storm events. All inspections should include investigation for potential sources of contamination.

Sediment Control

The basin should be designed to allow for maintenance. Access should be provided for vehicles to easily maintain the forebay (pre-settling basin) without disturbing vegetation or sediment any more than what is absolutely necessary.

Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well-established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass planted on basin side slopes should also prevent erosion.

Vegetation Maintenance

Maintenance of the vegetation on the basin floor and side slopes is necessary to promote a dense turf with extensive root growth, which subsequently enhances infiltration, prevents erosion and sedimentation, and deters invasive weed growth. Bare spots should be immediately stabilized and revegetated.

The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems, including groundwater pollution, for which the infiltration basin helps mitigate. Consult the VESCH, 1992 edition for appropriate fertilizer types and application rates.

## Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration basin.

1. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration basin application.

2. Determine if the soils (permeability, bedrock, water table, Karst, embankment foundation, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration basin application.

3. Locate the infiltration basin on the site within topographic constraints.

4. Determine the drainage area to the infiltration basin and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the infiltration basin:
   - Design infiltration rate, $f_d = 0.5 f$.
   - Max. Storage time $T_{max}$ = 48 hours
   - Max. Storage depth, $d_{max}$
   - Runoff pretreatment - concentrated input, sheet flow input, sediment forebay
   - Vegetated buffer around basin to filter surface runoff
   - Vegetated emergency spillway and/or riser and barrel design
   - Earthen Embankment design

7. Provide material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

## MINIMUM STANDARD 3.10B

# INFILTRATION TRENCH

### Definition

An infiltration trench is a shallow, excavated trench backfilled with a coarse stone aggregate to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into the surrounding soils from the bottom and sides of the trench. The trench can be either an open surface trench or an underground facility.

### Purpose

Infiltration trenches are used primarily as water quality BMPs. Trenches are generally 2 to 10 feet deep and are backfilled with a coarse stone aggregate, allowing for temporary storage of storm runoff in the voids between the aggregate material. Stored runoff gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed area with a surface inlet. Utilizing underground pipes within the trench can increase the temporary storage capacity of the trench and can sometimes provide enough storage for flooding and/or stream channel erosion control (see **Figure 3.10-3**).

### Conditions Where Practice Applies

An infiltration trench may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.
Infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

<u>Drainage Area</u>

Infiltration trenches are not practical for large drainage areas. Generally, the drainage area for infiltration trenches should be limited to 5 acres. Multiple trenches may be considered to control the runoff from a large site, but this also increases the associated maintenance responsibilities.

Development Conditions

Infiltration trenches are generally suited for low- to medium-density residential and commercial developments. They can be installed in multi-use areas, such as along parking lot perimeters, or in small areas that cannot readily support retention basins or similar structures. Infiltration trenches can be used in residential areas, commercial areas, parking lots and open space areas. Unlike most BMPs, trenches can easily fit into the margin, perimeter, or other unused areas of developed sites, making them particularly suitable for retrofitting in existing developments or in conjunction with other BMPs. A trench may also be installed under a swale to increase the storage of the related infiltration system. In all cases, pretreatment of the stormwater runoff to remove course sediment and particulate pollutants prior to entering the infiltration trench should be provided.

## Planning Considerations

Appropriate soil conditions and protection of groundwater are two important considerations when planning for an infiltration trench. For further discussion, refer to the **Planning Considerations** previously discussed in **General Infiltration Practices, Minimum Standard 3.10**.

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration trenches intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

General

Infiltration trenches are assumed to have rectangular cross-sections. Thus, the infiltration surface area (trench bottom) can be readily calculated from the trench geometry. The storage volume of the trench must be calculated using the void ratio of the backfill material that will be placed in it.

The same general criteria presented for the design of infiltration basins apply to trenches; the following information is provided for additional guidance.

Soils Investigation

A minimum of one soil boring log should be required for every 50 feet of trench length. A minimum of two soil boring logs should be required for each proposed trench location (Washington State DOE, 1992).

Topographic Conditions

Infiltration trenches should be located 20 feet down-slope and 100 feet up-slope from building foundations. An analysis should be completed to identify any possible adverse effects of seepage zones if there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. **The use of infiltration trenches on fill sites is not permitted**.

Design Infiltration Rate

The design infiltration rate, $f_d$, should be set to equal one-half the infiltration rate obtained from the soil analysis. Therefore,

$$f_d = 0.5\,f$$

Maximum Storage Time and Trench Depth

All infiltration trenches should be designed to empty within 2 days following the occurrence of a storm event. Thus, a maximum allowable storage time, $T_{max}$, of 48 hours should be used.

The maximum depth for an infiltration **trench** may be defined as:

$$d_{max} = \frac{f_d T_{max}}{V_r}$$

**Equation 3.10-5**
**Maximum Depth for Infiltration Trench**

where: $d_{max}$ = maximum allowable depth of the facility, in ft;
$f_d$ = design infiltration rate of the trench area soils, in ft/hr ($f_d = 0.5f$);
$T_{max}$ = maximum allowable drain time = 48 hrs.;
$V_r$ = void ratio of the stone reservoir expressed in terms of the percentage of porosity divided by 100 (0.4 typ.).

Refer to the Virginia Department of Transportation's Road and Bridge Specifications, latest edition, for information and specifications for coarse aggregates. A void ratio of 0.40 is assumed for stone reservoirs using 1.5 to 3.5 inch stone - VDOT No. 1 Coarse-graded Aggregate.

The minimum surface area of the facility bottom may be defined as:

$$SA_{min} = \frac{Vol_{wq}}{f_d T_{max}}$$

**Equation 3.10-6**
**Infiltration Trench Minimum Bottom Surface Area**

where: $SA_{min}$ = minimum trench bottom surface area, in $ft^2$;
$Vol_{wq}$ = water quality volume requirements, in $ft^3$;
$f_d$ = design infiltration rate of the trench area soils, in ft/hr ( $f_d = 0.5f$);
$T_{max}$ = maximum allowable drain time = 48 hrs.

Runoff Pretreatment

Infiltration trenches should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the trench. Vegetated filters, sediment traps or forbays, water quality inlets (refer to **Minimum Standard 3.15, Manufactured BMP Systems**) are just a few of the available pretreatment strategies. To reduce both the frequency of turbulent flow-through and the associated scour and/or resuspension of residual material, infiltration trenches and associated pretreatment facilities should be installed off-line (MWCOG, 1992). Additional pretreatment arrangements are illustrated in **Figure 3.10-3**. Refer to the discussion on **Sediment Control** in **General Infiltration Practices**, **Minimum Standard - 3.10**.

A grass strip or other type of vegetated buffer at least 20 feet wide should be maintained around trenches that accept surface runoff as sheet flow. The slope of the filter strip should be approximately 1% along its entire length and 0% across its width. A recent study by MWCOG (Galli, 1992) concluded that for areas receiving high suspended solid loads, a minimum filter length of 50 feet is desirable.

All trenches with surface inlets should be engineered to capture sediment from the runoff before it enters the stone reservoir. Any pretreatment facility design should be included in the design of the trench, complete with maintenance and inspection requirements.

Backfill Material

Backfill material for the infiltration trench should be clean aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches (i.e., VDOT No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size. Void spaces for VDOT No. 1 aggregate is assumed to be 40 percent.

An 8 inch deep bottom sand layer (VDOT Fine Aggregate, Grading A or B) is required for all trenches to promote better drainage and reduce the risk of soil compaction when the trench is backfilled with stone (MWCOG, 1992).

Filter Fabric

The aggregate fill material should be surrounded with an engineering filter fabric as shown in **Figure 3.10-5**. For an aggregate surface trench, filter fabric should surround all of the aggregate fill material except the top one foot. A separate piece of fabric should be used for the top layer to act as a failure plane. This top piece can then be removed and replaced upon clogging. Note, however, that filter fabric should **not** be placed on the trench bottom. Refer to the VESCH 1992 edition, for filter fabric specifications.

Overflow Channel

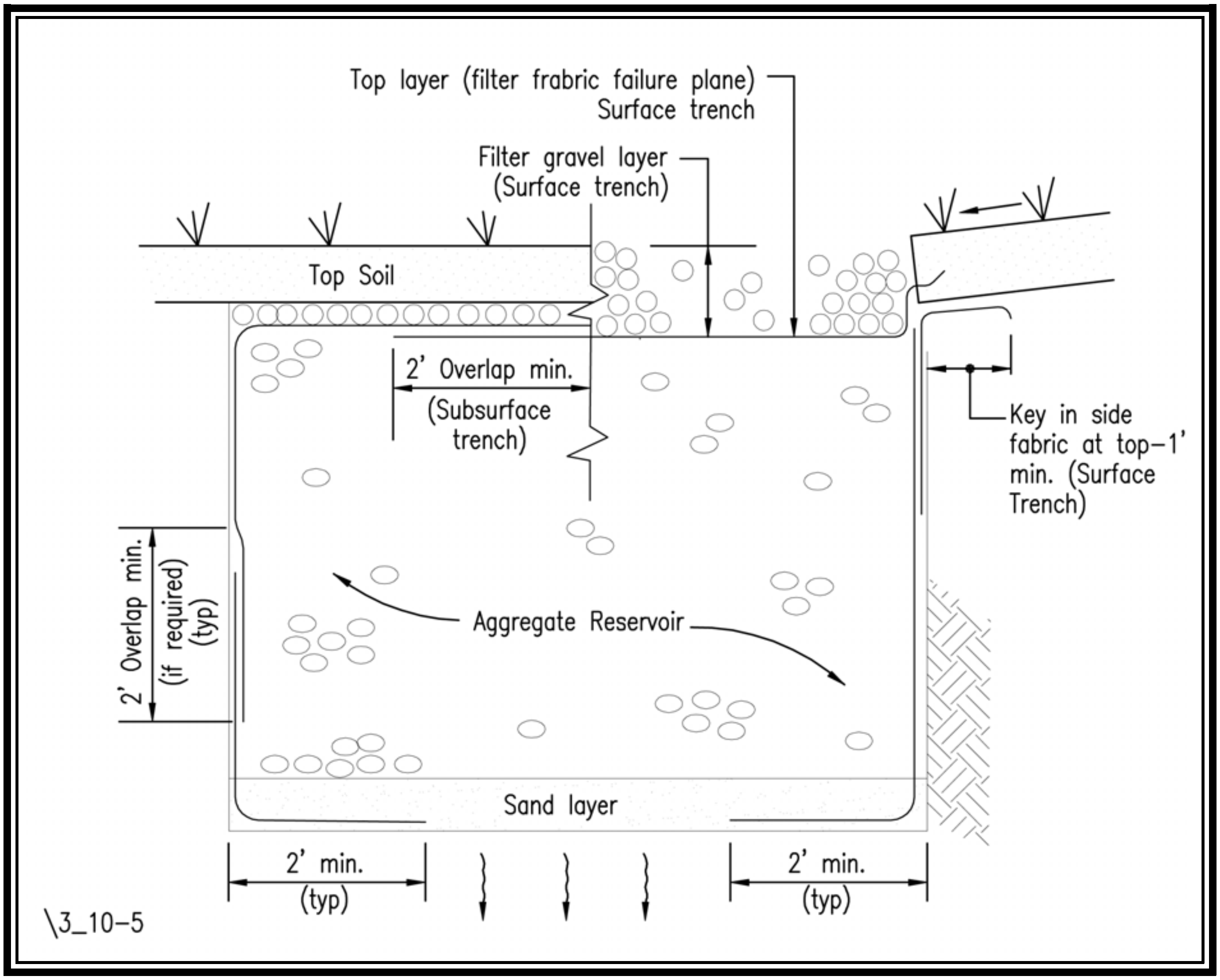
Usually, because of the small drainage areas controlled by an infiltration trench, an emergency spillway is not necessary. However, the overland flow path taken by the surface runoff, when the capacity of the trench is exceeded, should always be evaluated. A nonerosive overflow channel leading to a stabilized watercourse should be provided, as necessary, to insure that uncontrolled, erosive, concentrated flow does not develop.

Observation Well

An observation well should be installed for every 50 feet of infiltration trench length. The observation well will show how quickly the trench dewaters following a storm, as well as providing a means of determining when the filter fabric is clogged and maintenance is needed (refer to **Figure 3.10-4**).

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be installed in the center of the structure, flush with the ground elevation of the trench. Putting the observation well in a non-parking or traffic area to simplify inspections is best. The top of the well should be capped to discourage vandalism and tampering.

**FIGURE 3.10 - 5**
***Filter Fabric Placement***



## Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Construction of an infiltration trench should also be in conformance with the following:

### Sequence of Construction

An infiltration trench should not be constructed or placed into service until all of the contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed trench and/or pretreatment facility with a large volume of fine sediment.

The specifications for the construction of an infiltration trench should state the following: 1) *the earliest point at which storm drainage may be directed to the trench*, and 2) *the means by which this delay in use is to be accomplished*. Due to the wide variety of conditions encountered among development projects, each project should be evaluated separately to postpone trench use for as long as possible.

### Trench Preparation

Trench excavation should be limited to the specific trench dimensions. Excavated materials should be placed away from the trench sides to avoid impacting the trench wall stability.

The trench should be excavated with a backhoe or similar device that allows the equipment to stand away from the trench bottom. This bottom surface should be scarified with the excavator bucket teeth on the final pass to eliminate any smearing or shearing of the soil surface. Similarly, the sand filter material should be placed on the trench bottom so that it does not compact or smear the soil surface. The sand must be deposited ahead of the loader so the equipment is always supported by a minimum of 8 inches of sand.

Large tree roots must be trimmed flush with the trench sides to prevent the fabric from puncturing or tearing during subsequent installation procedures. No voids between the filter fabric and the excavation walls should be present. If boulders or similar obstacles are removed from the excavated walls, natural soils should be placed in these voids before the filter fabric is installed. The side walls of the trench should be roughened where sheared and sealed by heavy equipment.

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft cohesive or cohesionless soils predominate. These conditions may require that the side slopes be laid back to maintain stability; trapezoidal rather than rectangular cross sections may result.

Fabric Laydown

The roll of filter fabric should be cut to the proper width before installation. The width should allow for perimeter irregularities plus a minimum 12-inch overlap at the top. When a fabric overlap is required elsewhere, the upstream section should overlap the downstream section by a minimum of 2 feet to ensure that the fabric conforms to the excavation surface during aggregate placement. Note that filter fabric should **not** be placed on the trench bottom.

Stone Aggregate Placement Compaction

The crushed stone aggregate should be placed in the trench in loose lifts of about 12 inches using a backhoe or front-end loader with a drop height near the bottom of the trench, and should be lightly compacted with plate compactors. Aggregate should not be dumped into the trench by a truck.

Backfill material for the infiltration trench should be clean, washed aggregate *1.5* to *3.5* inches in diameter (VDOT No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size.

The 8 inch deep bottom sand layer should consist of VDOT Fine Aggregate, Grading A or B.

Overlapping and Covering

Following the stone aggregate placement, the filter fabric should be folded over the stone aggregate to form a 12-inch minimum longitudinal overlap. The desired fill soil or stone aggregate should be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Potential Contamination

Clean aggregate **should not** be mixed with natural or fill soils. All contaminated aggregate should be removed and replaced with clean aggregate.

Traffic Control

To prevent or reduce compaction of the soil, heavy equipment and traffic should not travel over the infiltration trench.

Observation Well

Observation wells should be provided as specified in the design criteria. The depth of the well at the time of installation should be clearly marked on the well cap.

## Maintenance / Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

The observation well and pretreatment facility should be monitored quarterly and after every large storm event. It is recommended that a log book be maintained showing the depth of water in the well at each observation in order to determine the rate at which the facility dewaters after runoff producing storm events. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data suggest that a more frequent schedule is required.

Sediment Control

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate should be provided when the trench has a stone surface. Sediment deposited should not be allowed to build up to the point where it will reduce the infiltration rate into the trench.

It is recognized that infiltration facilities are subject to clogging. Once a trench facility has clogged, very little can be done to correct it, short of excavating the facility. Maintenance efforts, therefore, should focus on the measures used for pretreatment of runoff, in addition to the facility itself.

Vegetation Maintenance

Any vegetated buffers associated with an infiltration trench should be inspected regularly and maintained as needed. Regular maintenance of the buffer is necessary to promote dense turf with extensive root growth, which subsequently enhances runoff filtering, prevents erosion and sedimentation, and deters invasive weed growth. Bare spots should be immediately stabilized and revegetated. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems which the infiltration basin helps to mitigate. Consult the VESCH 1992 edition for appropriate fertilizer types and application rates.

## Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration trench.

1. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration trench application.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration trench application.

3. Locate the infiltration trench on the site within topographic constraints.

4. Determine the drainage area for each infiltration trench and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the infiltration trench:
   - design infiltration rate, $f_d = 0.5\,f$
   - max. storage time $T_{max}$ = 48 hours
   - max. storage depth, $d_{max}$
   - stone backfill of clean aggregate (1.5" to 3.5") VDOT No. 1 Open-Graded Course Aggregate
   - sand layer on trench bottom (8 inches)
   - runoff pretreatment - concentrated input, sheet flow input
   - vegetated buffer around trench to filter surface runoff
   - filter fabric on trench sides and top (not on trench bottom) keyed into trench
   - overflow channel or large storm bypass
   - observation well

7. Provide material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

## MINIMUM STANDARD 3.10C

# ROOF DOWNSPOUT SYSTEM

### Definition

A roof downspout system is an infiltration trench practice intended only for infiltrating rooftop runoff transported to the trench via roof downspout drains.

### Purpose

The purpose of a roof downspout system is to provide water quality enhancement of rooftop runoff via infiltration of the water quality volume into the surrounding soils. This facility is not designed to infiltrate other surface water that could transport sediment or pollutants, such as from paved areas.

### Conditions Where Practice Applies

Roof downspout systems may be used in any situation where disposing of rooftop runoff without direct connections to existing drainage systems or BMPs is acceptable and advantageous. Because of their small size, they are well suited for retrofitting in areas where runoff control of existing or new rooftop areas associated with building additions becomes necessary. As part of a low impact development strategy, roof downspout systems effectively disconnect the rooftop imperviousness from the drainage system which helps reduce the stormwater impact of the development. Use of roof downspout systems (or infiltration trenches in general) in residential areas should be used with caution due to concern for the potential lack of inspections and maintenance, and ultimate failure and abandonment of the facility.

### Planning Considerations

The planning considerations for roof downspout systems are the same as those for infiltration trenches (**Minimum Standard 3.10B**). The drainage area is limited to the rooftop areas of residential and/or commercial structures.

## Design Criteria

This section provides recommendations and minimum criteria for the design of roof downspout systems intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

The design criteria for roof downspout systems are the same as those for infiltration trenches with the following exceptions and/or additions:

Distance from Structures

Roof downspout systems should be a minimum of 10 feet down-slope from any structure or property line, and 30 feet from any septic tank or drain field.

Runoff Pre-Treatment

Gutters should be fitted with mesh screens to prevent leaf litter and other debris from entering the system in areas where there is tree cover. The expected growth of newly planted trees should be considered.

A pretreatment settling basin as shown in **Figure 3.10-6** should be provided on all roof downspout systems.

Overflow

An overflow outlet should be provided on the downspout at the surface elevation to allow flow to bypass the infiltration facility when it is full or clogged. (See **Figure 3.10-6**.)

Adequate surface drainage away from the structure should be provided according to appropriate building codes.

## Construction Specifications

The construction specifications for roof downspout systems are the same as those for infiltration trenches.

## Maintenance and Inspection Guidelines

Maintenance procedures are identical for those of an infiltration trench. Since these facilities are installed on individual buildings and other structures, provisions need to be made for their maintenance, especially when they are installed on single family dwellings. When flow is observed to be bypassing the facility, the system has clogged and should be evaluated for rehabilitation.

## Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of a roof downspout system.

1. Determine if the anticipated development conditions and rooftop areas are appropriate for a roof downspout system.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for a roof downspout system.

3. Locate the roof downspout system on the site within site topographic constraints.

4. Determine the roof area for each roof downspout system and calculate the required water quality volume.

5. Design the roof downspout system:
   - design infiltration rate, $f_d = 0.5 f$
   - max. Storage time $T_{max} = 48$ hours
   - max. Storage depth, $d_{max}$
   - stone backfill of clean aggregate (*1.5*" to *3.5*" diameter) - VDOT No. 1 Open-graded Course Aggregate
   - sand layer on trench bottom (*8* inches
   - runoff pretreatment - concentrated input: gutter screens, settling basin
   - filter fabric on trench sides and top (not on trench bottom) keyed into trench
   - overflow channel or large storm bypass
   - observation well

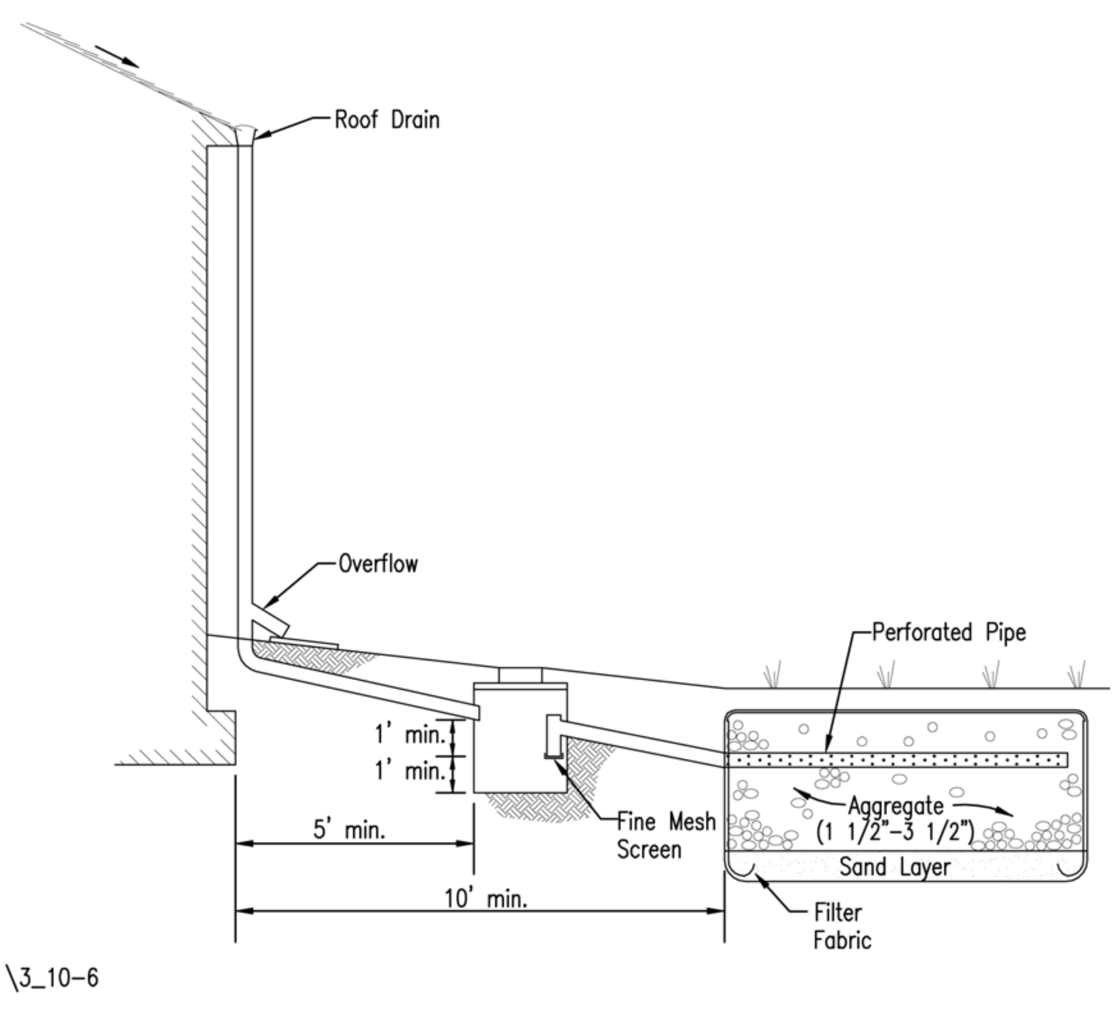
6. Provide material specifications.

7. Provide sequence of construction.

8. Provide maintenance and inspection requirements.

**FIGURE 3.10 - 6**

***Roof Downspout System with a Pretreatment Sump Basin***



## MINIMUM STANDARD 3.10D

# POROUS PAVEMENT

### Definition

Porous pavement is a pervious pavement placed over a stone reservoir that is installed above a permeable soil.

The two pavements discussed in this section are ***porous asphalt pavement*** and ***porous concrete pavement***. *Porous asphalt pavement* is an open-graded coarse aggregate, bound together by asphalt cement into a coherent mass, with sufficient interconnected voids to provide a high rate of permeability to water. A typical porous asphalt pavement cross-section is presented in **Figure 3.10-11**. *Pourous concrete pavement* consists of specially formulated mixtures of Portland Cement, uniform, open-graded coarse aggregate and potable water.

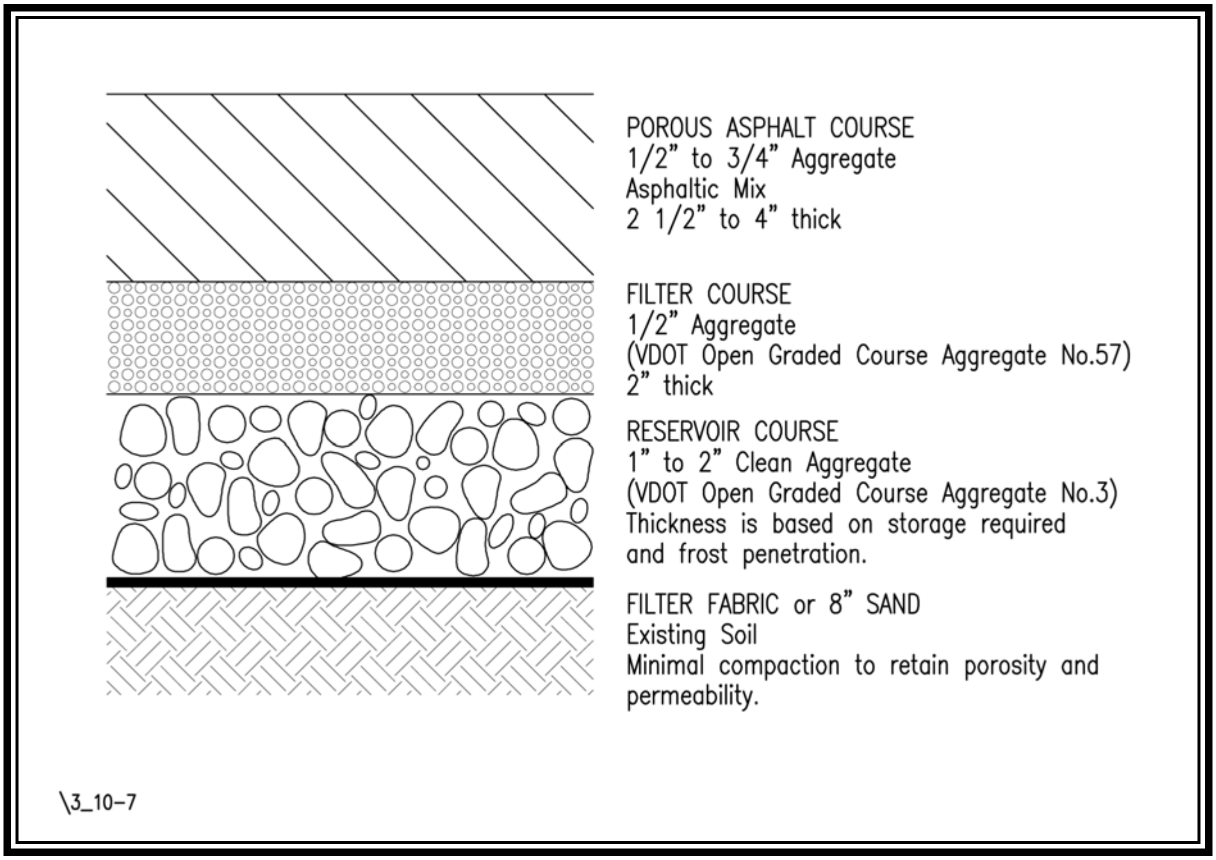
### Purpose

The purpose of porous pavement is to provide water quality enhancement by infiltrating water through the paved surface and stone reservoir and into the underlying soils.

### Conditions Where Practice Applies

Porous pavement is applicable as a substitute for conventional asphalt pavement on parking areas and low-traffic roadways if the grades, subsoil drainage characteristics and groundwater table conditions are suitable. Usually, the grades should be very gentle to flat, subsoil should have moderately rapid permeability ( $f > 0.52$ *in/hr*) and the depth to the water table or bedrock should be at least 3 feet below the bottom of the stone reservoir. Parking lots, especially fringe or overflow parking areas, are suited for use with this paving material. Porous pavement should generally be installed on sites from 1/4 to 10 acres.

**FIGURE 3.10 - 7**
***Porous Pavement Section***




## Planning Considerations

Porous pavement functions similar to infiltration trenches and, therefore, has similar planning considerations. Appropriate soil conditions and the protection of groundwater are among the important considerations which may limit its use. Refer to the **Planning Considerations** in **General Infiltration Practices**, **Minimum Standard 3.10** for additional discussion.

Generally, groundwater recharge rates are slightly higher under a porous pavement than under natural conditions, as vegetation is absent and water is not transpired during the summer months. Between 60% and 90% of the annual rainfall volume deposited on a porous pavement percolates into the ground (Washington DOE, 1992.)

It has been shown that porous pavement is more skid-resistant than conventional pavement in rainy weather and that the markings on a porous pavement are easier to see on rainy nights. In addition, studies have suggested that porous asphalt pavement is sufficiently strong and able to withstand freeze-thaw cycles and will last as long, structurally, as conventional pavement.

Typically, porous pavement is slightly more expensive than regular pavement. Additional costs associated with critical installation procedures and the availability of the asphalt mix may be offset by eliminating the need for curb and gutter, inlets, and conveyance systems. Availability is a consideration, since asphalt producers may not be willing to provide porous asphalt for small projects due to the demand for conventional asphalt mixes. For the production of a porous pavement mixture, the asphalt plant must be cleaned out to remove the fines not wanted in the porous mix. The cost of the stone reservoir and filter fabric associated with porous pavement is offset by the amount that would be spent on a stormwater facility elsewhere on the site.

Installation requires a very high level of workmanship throughout the construction process; porous pavement must be handled with great care in order for it to retain its porous qualities. Many pavement contractors and pavement engineers have limited experience in designing and constructing porous pavement. Improper installation can render a porous pavement design inoperative from the outset.

The biggest drawback to porous pavement is its tendency to clog if improperly maintained. Once it is clogged, it may have to be completely replaced since rehabilitating it is difficult and costly. On going maintenance of the pavement surface and specific limitations on the methods of snow and ice removal are often ignored and/or forgotten over time and with transfers of ownership. Clogging of the pavement surface from construction-related erosion can be prevented by waiting until all other phases of construction are complete and vegetation is stabilized before installing the pavement. Clogging of the pavement surface from natural circumstances is best prevented by installing it in areas that do not have highly erodible soils or steep slopes adjacent to the paved area.

Certain features can be incorporated into the design of porous pavement facilities to prolong the effective life of the system. One such feature is to "daylight" the aggregate base along the downslope edge of the pavement, forming a chimney drain into the stone storage under the pavement. The runoff can flow into the stone storage through the chimney drain if the pavement clogs.

If slow infiltration rates in the subgrade exist, porous pavement systems can be designed with an underdrain or collector system. When the collector system has a restriction plate on the outlet that controls the discharge, the stone reservoir can be designed as an underground stone-storage detention facility.

Evidence suggests that pollutants adsorb to the aggregate material, while particulates settle to the bottom of the aggregate layer. However, the target removal efficiency of 50% to 65%, as presented in **Table 3.10-1** for infiltration facilities, is too high for a stone-storage facility. **Therefore, a**

**porous pavement facility with a stone storage underdrain system that provides positive drainage will be considered an extended-detention or detention facility**. Its target pollutant removal efficiency will be based on the storage and release rate characteristics of these facilities as presented in **Minimum Standards 3.07, Extended-Detention**; and **3.08, Detention Basins**, until more information is collected to support the use of a higher pollutant removal efficiency.

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of porous pavement intended to comply with the runoff quality requirements of theVirginia Stormwater Management programs.

The general design criteria for the porous pavement stone reservoir area and the underlying soils are the same as for infiltration trenches. Additional design is required for determining the porous pavement thickness. The design of the pavement is dependent on the strength of the sub-base soil, the projected traffic intensities, and the storage capacity of the reservoir and base.

A thorough examination of the site is of primary importance to the proper design and functioning of porous pavement. Soil and climate conditions, expected surface wear, and the use objectives of the porous surface should all be considered before designing the pavement.

The following represents a general list of design elements that should be considered in any porous pavement design:

1. Anticipated traffic intensities, defined by the ***average daily equivalent axle load*** (*EAL*).
2. ***California Bearing Ratio*** (CBR) of the soils.
3. Susceptibility of the soils to frost heave.

**Due to the complexity of its design, a step-by-step procedure to engineer a porous pavement section will not be presented in this manual**. **A professional engineer, with training and experience in porous pavement design and construction, should design the pavement section and supervise during the paving operation**.

Specific design requirements for a satisfactory ***porous asphalt pavement*** section equivalent to a conventional pavement design are available through the U. S. Department of Transportation's Federal Highway Administration and through other references listed at the end of this standard.

Specific design requirements for a satisfactory ***porous concrete pavement*** section are available through the Florida Concrete and Products Association, 649 Vassar Street, Orlando, Florida 32804. Other references are also listed at the end of this standard.

## *Porous Concrete Pavement* Construction Specifications

The design criteria and material specifications for ***porous concrete pavement*** are **NOT INCLUDED** in this manual due their extreme complexity. Note that the methods of handling and placing porous concrete are different from other types of concrete. **Only concrete firms and contractors familiar with the intricacies of porous concrete should be used**. For further discussion, refer to **General Pavement Design Criteria** above.

## *Porous Asphalt Pavement* Construction Specifications

The following construction specifications are general and typically represent aspects of design that require fine-tuning based on site conditions. A professional with experience in porous asphalt design should supervise construction to insure proper methods are used.

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures specified for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

The specifications for the asphalt mix should include:

1. Calculation of void space in the asphalt section.
2. Aggregate type, quality and gradation.
3. Asphalt cement grade in mix.
4. Asphalt content in mix.
5. Mixing temperature.

Construction of a porous asphalt pavement should also be in conformance with the following (adapted from Construction Sspecifications for the City of Rockville, Maryland:

Stabilization

To preclude premature clogging and/or failure, porous asphalt pavement should not be placed into service until all of the surface drainage areas contributing to the paved area have been effectively stabilized. Refer to the VESCH 1992 edition, for stabilization requirements.

Subgrade Preparation

1. Alter and refine the grades as needed to bring subgrade to required grades and sections as shown in the drawings.

2. The type of equipment used in subgrade preparation should not cause undue subgrade compaction. (Use tracked-equipment or equipment with oversized rubber tires **Do Not use standard rubber tire equipment**.) Traffic over the subgrade should be kept to a minimum. Where fill material is required, it should be compacted to a density equal to the undisturbed subgrade. Inherent soft spots should be corrected.

Trench Bottom

The trench bottom may be lined with filter fabric or an *8* inch layer of sand (VDOT Fine Aggregate, Grading A or B), based on the geotechnical and pavement design recomendations.

Reservoir course

1. The stone reservoir course aggregate should be 1 to 2 inch diameter clean, washed, crushed stone meeting VDOT specifications (Open Graded Course Aggregate No. 3).

2. The stone reservoir thickness (depth) is dependent on the storage volume requirements (water quality volume, quantity control volumes, etc.).

Filter Course

1. The filter course aggregate should be 1/2-inch diameter clean, washed, crushed stone, meeting VDOT specifications (Open-graded Course Aggregate No. 57).

2. The filter course thickness should be 2 inchs.

Porous Asphalt Surface Course

1. The surface course should be laid directly over the aggregate base course and should be laid in one lift.

2. The laying temperature should be between 230EF and 260EF, with a minimum air

temperature of 50EF, to make sure that the surface does not stiffen before compaction.

3. Compaction of the surface course should be completed while the surface is cool enough to resist a 10-ton roller. One or two passes of the roller are required for proper compaction. More rolling could cause a reduction in the surface course porosity.

4. The mixing plant should certify to the aggregate mix, the abrasion loss factor, and the asphalt content in the mix. The asphalt mix should be tested for its resistance to stripping by water using ASTD 1664. If the estimated coating area is not above 95%, antistripping agents should be added to the asphalt.

5. The mix should be transported to the site in a clean vehicle with smooth dump beds sprayed with a non-petroleum release agent. The mix should be covered during transportation to control cooling.

6. The asphalt mix should be 5.5 to 6% of dry aggregate by7 weight.

7. The asphalt's grade should meet AASHTO Specification M-20; 85 to 100% penetration road asphalt as a binder in the western part of the state, 65 to 80% in the piedmont area, and 50 to 65% in southeastern Virginia.

8. The aggregate grading should be as specified in **Table 3.10-3**.

Protection

After final rolling, no vehicular traffic of any kind should be permitted on the pavement until cooling and hardening has taken place, and never less than 6 hours (preferably 24 to 48 hours). All construction related traffic should be routed around or away from the porous pavement.

Workmanship

1. Work should be completed with expertise throughout the process and without staining or damage to other permanent work.

2. The transition between existing and new paving work should be neat and flush.

3. Finished paving should be even, without pockets, and graded to elevations shown.

4. All minor surface projections and edges adjoining other materials should be ironed smoothly to grade.

Certification

An appropriate professional should certify that these specifications were followed.

**TABLE 3.10 - 3**
***Porous (Open-graded) Asphalt Concrete Formulation****

| PROBABLE PARTICLE DATA | | | | | | |
|---|---|---|---|---|---|---|
| **Material** | **Screen** | **Weight** *%* | **Volume** *%* | **Width** *mm* | **Weight** *g* | **No. In 100g of Asphalt Concrete** |
| Aggregate | Through ½ | 2.8 | 2.2 | 10.7 | 1.667 | 1.7 |
| | Through 3/8 | 59.6 | 46.3 | 8.0 | .697 | 85.5 |
| | Through #4 | 17.0 | 13.3 | 4.0 | .087 | 195.4 |
| Sub-Total Coarse Aggregate | | 79.4 | 61.8 | | | 282.6 |
| | Through # 8 | 2.8 | 2.2 | 2.0 | .0109 | 255.6 |
| | Through #16 | 10.4 | 8.0 | 1.0 | .00136 | 7647. |
| | Through 200 | 1.9 | 1.5 | .06 | .000294 | 6462. |
| Asphalt | | 5.5 | 10.5 | | | |
| Air | | 0 | 16.0 | | | |
| | | | | | | |
| TOTAL | | 100.0 | 100.0 | | | |

** Source: City of Rockville, Maryland (1982).*

## Maintenance and Inspections

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific applications may require other measures not discussed here.

Inspection Schedule

The observation well should be checked quarterly and after every large storm event. It is recommended that a log book be maintained showing the depth of water in the well during each inspection in order to determine the rate at which the facility dewaters after runoff producing storms events. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data suggest that a more frequent schedule is required.

Maintenance

The surface of porous asphalt pavement must be cleaned regularly to prevent it from becoming clogged by fine material. This cleaning is best accomplished through the use of a vacuum cleaning street sweeper, followed by high pressure water washing. Outside of regular cleaning, porous pavement requires maintenance similar to that of regular pavement. In times of heavy snowfall, however, application of abrasive material should be closely monitored to avoid clogging problems once the snow and ice has melted. There are no maintenance measures designed to repair fully clogged porous pavement, other than replacement.

## Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration trench.

1. Determine if the anticipated development conditions and drainage area are appropriate for a porous pavement application.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and site topographic conditions (slopes, etc.) are appropriate for a porous pavement application.

3. Locate the porous pavement section on the site within the topographic constraints.

4. Determine the drainage area for the porous pavement and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the porous pavement stone reservoir:
   - design infiltration rate, $f_d = 0.5\,f$
   - max. storage time $T_{max}$ = 48 hours
   - max. storage depth, $d_{max}$
   - stone backfill of clean aggregate (1.5" to 3.5") VDOT No. 1 Open-graded Course Aggregate
   - filter gravel layer - two inches of clean aggregate (1/2") VDOT No. 57 Open-graded Course Aggregate
   - sand layer on trench bottom (8 inche), or filter fabric, per geotechnical and pavement design recommendations
   - Filter fabric on trench sides and top (not on trench bottom) keyed into trench
   - Overflow channel or large storm bypass
   - Observation well

7. Provide pavement section design and material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

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Chapter 3.10

Surface Infiltration Trench. Note grass strip pre-treatment holds heavier particulate pollutants within paved area.

Porous Pavement Infiltration. Testing new pavement installation. Note: steady flow passes through pavement and into stone storage below with minimal spread.

# General Infiltration Practices

Infiltration Basin serves as landscaped pedestrian area during dry periods.

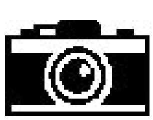

Infiltration Trench with concrete parking pavers in office park setting.

# General Infiltration Practices

# *MINIMUM STANDARD 3.11*

# BIORETENTION BASIN PRACTICES





View BMP Images

# LIST OF ILLUSTRATIONS

# LIST OF ILLUSTRATIONS Contd.

| # | TABLES | PAGE |
|---|---|---|

## MINIMUM STANDARD 3.11

# BIORETENTION BASINS

### Definition

Bioretention is an innovative BMP developed by the Prince George's County, Maryland Department of Environmental protection. The following information is drawn from their ***Design Manual for Use of Bioretention in Stormwater Management*** (P.G. County, 1993) unless otherwise noted. This technology is also referred to as "Rain Gardens."

**Figure 3.11-1** illustrates the Maryland bioretention (Rain Garden) concept as adapted for use in Virginia. There are seven major components to the bioretention area (Rain Garden): 1) the grass buffer strip; 2) the ponding area; 3) the surface mulch and planting soil; 4) the sand bed (optional); 5) the organic layer; 6) the plant material, and 7) the infiltration chambers. Each component is critical to sustaining a properly functioning BMP.

### Purpose

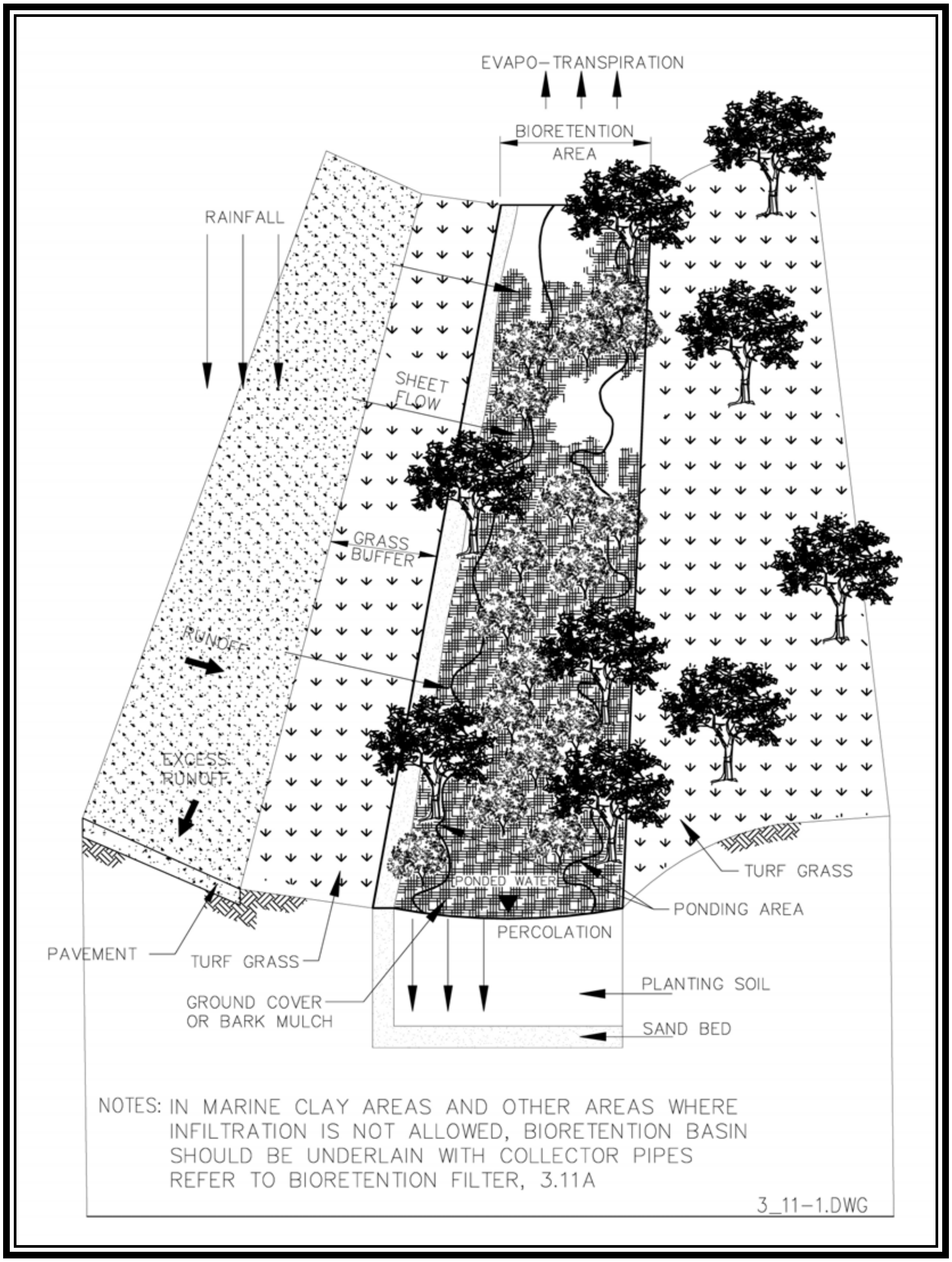
Bioretention basins are used primarily for water quality control. However, since they capture and infilter part of the stormwater from the drainage shed, they may provide partial or complete control of streambank erosion and partial protection from flooding (depending on the volume of water being captured and infiltered).

Bioretention facilities (Rain Gardens) are planting areas installed in shallow basins in which the stormwater runoff is treated by filtering through the bed components, biological and biochemical reactions within the soil matrix and around the root zones of the plants, and infiltration into the underlying soil strata. Properly constructed bioretention areas replicate the ecosystem of an upland forest floor through the use of specific shrubs, trees, ground covers, mulches and deep, rich soils. Since almost all bioretention basins are intended to be visual landscape amenities as well as stormwater BMPs, aesthetic considerations may be equally as important in their use as proper engineering. Bioretention design requires participation by a person with appropriate design skills and a working knowledge of indigenous horticultural practices, preferably a Landscape Architect.

Water Quality Enhancement

Bioretention basins enhance the quality of stormwater runoff through the processes of adsorption, filtration, volitization, ion exchange, microbial and decomposition prior to exfiltration into the surrounding soil mass. Microbial soil processes, evapotranspiration, and nutrient uptake in plants also come into play (Bitter and Bowers, 1995).

**FIGURE 3.11 - 1**
*Bioretention Basin*



The **grass buffer strip** filters particles from the runoff and reduces its velocity. The **sand bed** further slows the velocity of the runoff, spreads the runoff over the basin, filters part of the water, provides for positive drainage to prevent anaerobic conditions in the planting soil and enhances exfiltration from the basin. The **ponding area** functions as storage of runoff awaiting treatment and as a presettling basin for particulates that have not been filtered out by the grass buffer. The **organic or mulch layer** acts as a filter for pollutants in the runoff, protects the soil from eroding , and provides an environment for microorganisms to degrade petroleum-based solvents and other pollutants. The **planting soil layer** nurtures the plants with stored water and nutrients. Clay particles in the soil adsorb heavy metals, nutrients, hydrocarbons, and other pollutants. The **plant species** are selected based on their documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer (*ibid*). By providing a variety of plants, monoculture susceptibilities to insect and disease infestation are avoided, and evapotranspiration is enhanced. The **vented infiltration chambers** provide unobstructed exfiltration through the open-bottomed cavities, decrease the ponding time above the basin, and aerate the filter media between storms through the open chamber cavities and vents to grade, preventing the development of anaerobic conditions. By providing a valve equipped drawdown drain to daylight, the basin can be converted into a soil media filter should exfiltration surface failures occur.

Perforated underdrain systems are recommended for facilities placed in residential areas and in all areas where the in-situ soils are questionable. Refer to **3.11A - Bioretention Filter**.

The minimum width for a bioretention area is usually 10 feet, although widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip. The minimum length should be 15 feet (for lengths greater than 20 feet, the length should be at least twice the width to allow dispersed sheet flow). As an infiltration BMP, the maximum ponding depth is restricted to six inches to restrict maximum ponding time to preclude development of anaerobic conditions in the planting soil (which will kill the plants) and to prevent the breeding of mosquitoes and other undesirable insects in the ponded water. The planting soil must have sufficient depth to provide appropriate moisture capacity, create space for the root systems, and provide resistance from windthrow (Minimum depth equal to the diameter of the largest plant root ball plus 4 inches).

**Table 3.11-1** contains the target removal efficiencies once a **mature** plant community is created in the bioretention areas based on the volume of runoff to be captured and infiltered.

Flood Control and Channel Erosion

The amount of flood and channel erosion control provided by bioretention basins depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined. As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

**TABLE 3.11-1**
***Pollutant Removal Efficiencies for Bioretention Basins***

| BMP Description | Target Phosphorus Removal Efficiency |
|---|---|
| Bioretention basin with capture and treatment volume equal to 0.5 inches of runoff from the impervious area. | 50% |
| Bioretention basin with capture and treatment volume equal to 1.0 inches of runoff from the impervious area. | 65% |

## Conditions Where Practice Applies

Bioretention basins are suitable for use on any project where the subsoil is sufficiently permeable to provide a reasonable rate of infiltration and where the water table is sufficiently lower than the design depth of the facility to prevent pollution of the groundwater. Bioretention basins are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal efficiency. **Figures 3.11-2** through **3.11- 5** illustrate several applications. Bioretention basins may also be installed in off-line pockets along the drainage swales adjacent to highways or other linear projects, as illustrated in **Figure 3.11-6**. For large applications, several bioretention basins connected by an underground infiltration trench ("Green Alleys") are preferable to a single, massive basin. Such a system is especially desirable along the landward boundary of reduced Chesapeake Bay Resource Protection Areas. **Minimum Standard 3.11B** discusses this system. Considering the character of bioretention basins, some jurisdictions may qualify them as buffer restoration.

**FIGURE 3.11 - 2**
***Bioretention Basin at Edge of Parking Lot With Curb***

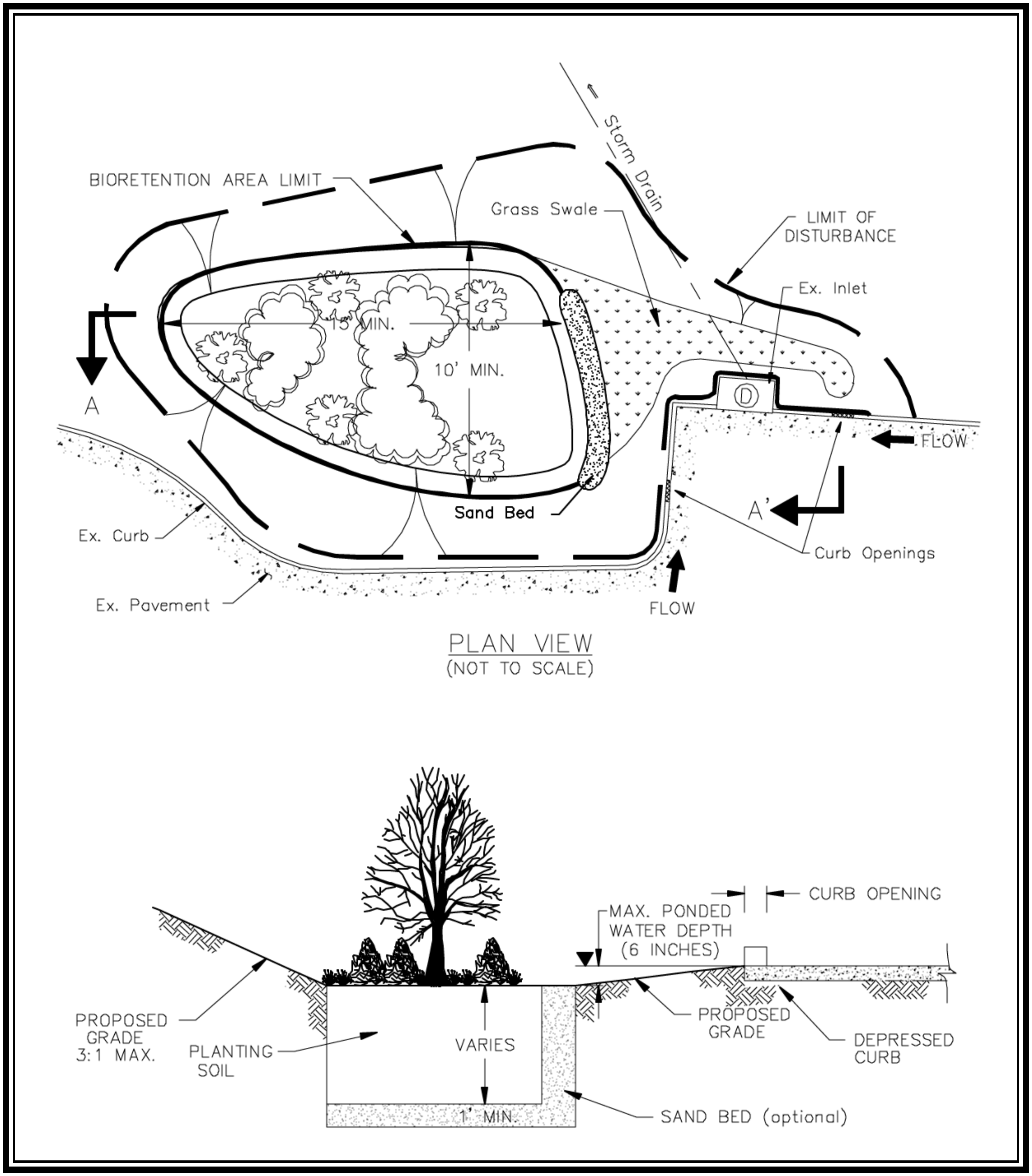


**FIGURE 3.11 - 3**
***Bioretention Basin in a Planting Island in a Parking Lot***

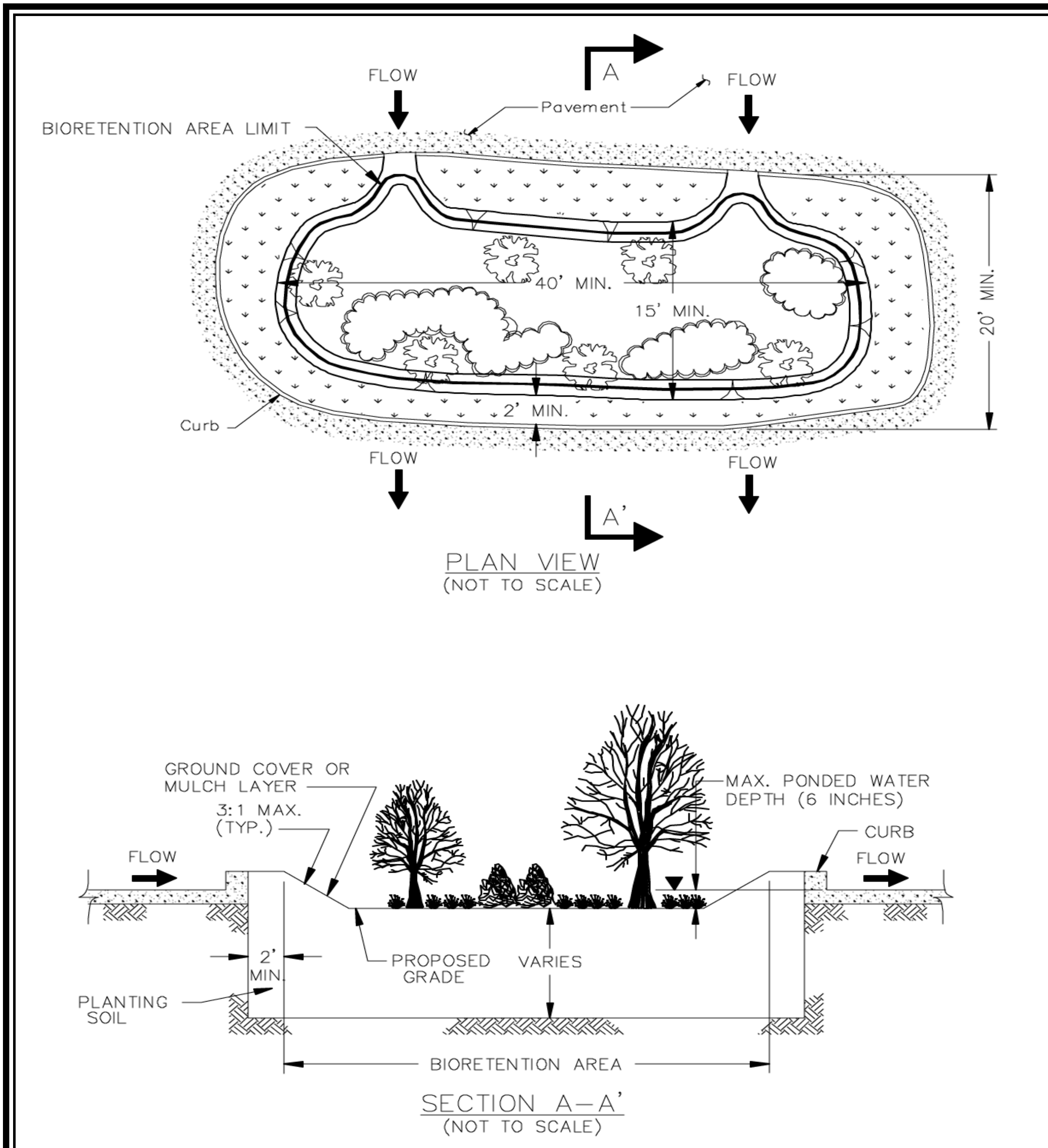


**FIGURE 3.11-4**
***Bioretention Basin Adjacent to a Drainage Swale***

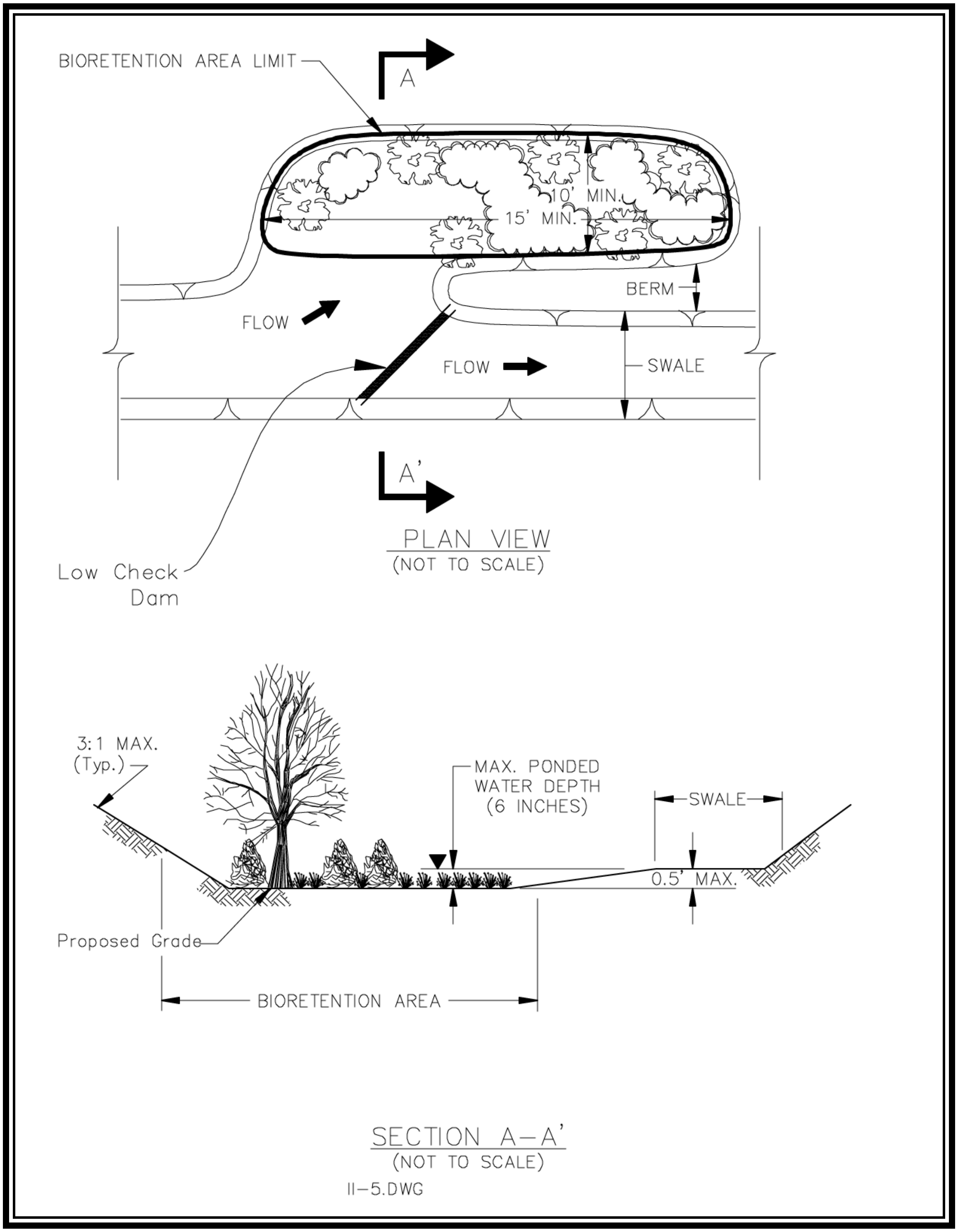
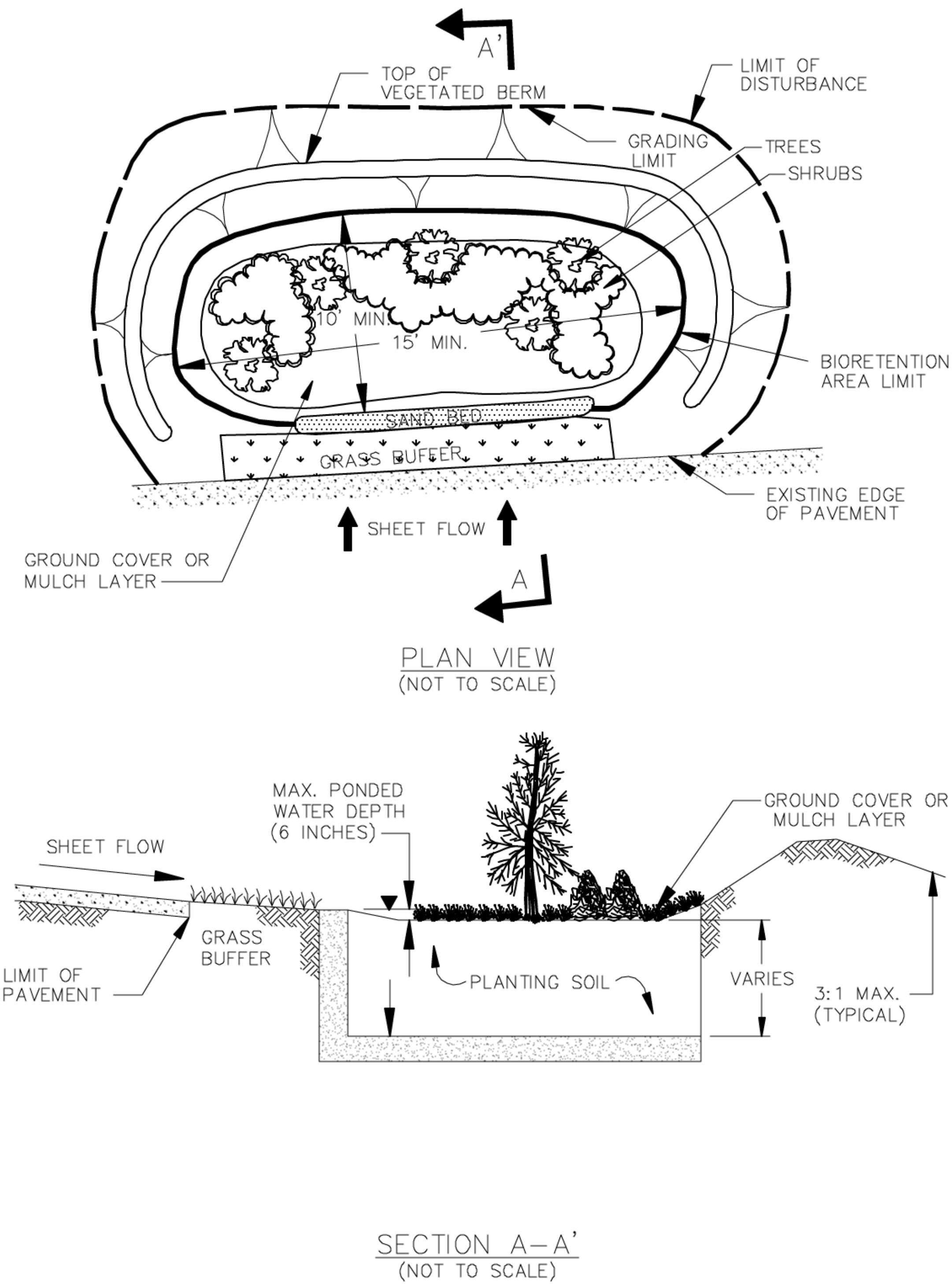


**FIGURE 3.11-5**
***Bioretention Basin at Edge of Parking Lot Without Curbs***



## Planning Considerations

Site Conditions

All of the Site Conditions considerations for general infiltration practices contained in **MINIMUM STANDARD 3.10** also apply to bioretention basins. Designers should also be mindful of local requirements for soil studies for infiltration practices such as those in the ***Northern Virginia BMP Handbook***. In addition to site conditions affecting infiltration practices in general, the following apply specifically to bioretention basins. The application of individual bioretention basins will usually be limited to drainage areas from 0.25 to 1 acre. Generally, commercial or residential drainage areas exceeding 1 acre in size will discharge sheet flows greater than 5 cfs.

### 1. Location Guidelines

Preferable locations for bioretention basins include 1) areas upland from inlets or outfalls that receive sheet flow from graded areas, and 2) areas of the site that will be excavated or cut. When available, areas of loamy sand soils should be used since these types of soils comprise the planting soils for bioretention basins. Locating the BMP in such natural locations would eliminate the cost of importing planting soils (see soil and organic specification under **Design Considerations**). BMP location should be integral with preliminary planning studies.

The following areas would be **undesirable** for bioretention basins: 1) areas that have mature trees which would have to be removed for construction of the bioretention basin, 2) areas that have existing slopes of 20% or greater, and 3) areas above or inclose proximity to an unstable soil strata such as marine clay.

### 2. Sizing Guidelines

For planning purposes, assume that the floor area of the bioretention basin will be a minimum of 2.5% of the impervious area draining to the basin if the first 0.5 inches of runoff is to be treated and a minimum of 4.0% of the impervious area on the drainage shed if the first 1.0 inches of runoff is to be treated. Derivation of these values is discussed below under **Design Considerations**. Note that small projects such as single family residences will likely default to the minimum 150 square foot area (10' X 15').

### 3. Aesthetic Considerations

Aesthetic considerations of the bioretention basin must be considered early in the site planning process. While topography and hydraulic considerations may dictate the general placement of such facilities, overall aesthetics of the site and the bioretention basins must be integrated into the site plan and stormwater concept plan from their inception. Both the stormwater engineer and the Landscape Architect must participate during the layout of facilities and infrastructure to be placed on the site. Bioretention design must be an integral part of the site planning process.

Sediment Control

Like other infiltration practices, provisions for long-term sediment control must be incorporated into the design, **as well as precautions during on-site construction activities.** Careful consideration must be given **in advance of construction** to the effects of work sequencing, techniques, and equipment employed on the future maintenance of the practice. Serious maintenance problems can be averted, or in large part, mitigated, by the adoption of relatively simple measures during construction.

**1. Construction Runoff**

***Bioretention basin BMPs should be constructed AFTER the site work is complete and stabilization measures have been implemented. If this is not possible, strict implementation of E&S protective measures must be installed and maintained in order to protect the bioretention facility from premature clogging and failure.***

Like other infiltration BMPs, bioretention basins constructed prior to full site stabilization will become choked with sediment from upland construction operations, rendering them inoperable from the outset. Simply providing inlet protection or some other filtering mechanism during construction will not adequately control the sediment. One large storm may completely clog the bioretention basin, requiring complete **reconstruction**.

Experience with infiltration practices has also demonstrated that the bioretention basin site should **NOT** be used as the site of sedimentation basins during construction. Such use tends to clog the underlying strata and diminish their capacity to accept infiltration below that indicated in preconstruction soil studies.

Bioretention basins are landscape amenities and should be installed with other landscaping as the last stage of project construction.

A detailed sediment control design to protect the bioretention basin **during** its construction should be included with the facility design. The ***Virginia Erosion and Control Handbook*** (VDCR, 1992), ***Standards and Specifications for infiltration Practices*** (Md. DNR, 1984), and ***Controlling Urban Runoff*** (MWCOG, 1987) provide technical guidance on sediment control designs.

***Experience with bioretention basins in Maryland has demonstrated that they must be protected until the drainage areas contributing to the practice have been adequately stabilized (P.G. Co., 1993).***

The definition of the term "adequately stabilized" is critical to the success of the facility. At the conclusion of construction activity, the temporary erosion and sediment control measures are usually removed at the direction of the erosion and sediment control inspector when, at a minimum, stabilization measures such as seed and mulch are in place. This does not mean, however, that stabilization has actually occurred. Bioretention basins must be protected until stabilization of the upland site is functioning to control the sediment load from denuded areas. Provisions to bypass the stormwater away from the bioretention basin during the stabilization period should be implemented.

## 2. Urban Runoff

A fully stabilized site will generate particulate pollutant load resulting from natural erosion, lawn and garden debris such as leaves, grass clippings, mulch, roadway sand, etc. Pretreatment of runoff to remove sediments prior to entering the bioretention basin is usually provided by a grass filter strip or grass channel. When runoff from sheet flow from such areas as parking lots, residential yards, etc., is involved, a grass filter strip, often enhanced with a pea gravel diaphragm, is usually employed. **Table 3.11-2** provides sizing guidelines as a function of inflow approach length, land use, and slope. The minimum filter strip length (flow path) should be 10 feet.

**TABLE 3.11-2**
***Pretreatment Filter Strip Sizing Guidance***
**(Source: Claytor and Schueler, 1996)**

| Parameter | Impervious Parking Lots | | | | Residential Lawns | | | | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Maximum Inflow Approach Length (feet) | 35 | | 75 | | 75 | | 150 | | |
| Filter Strip Slope | ≤ 2% | ≥2% | ≤2% | ≥2% | ≤2% | ≥2% | ≤2% | ≥2% | Maximum = 6% |
| Filter Strip Minimum Length | 10' | 15' | 20' | 25' | 10' | 12' | 15' | 18' | |

For applications where concentrated runoff enters the bioretention basin by surface flow, such as through a slotted curb opening, a grassed channel, often equipped with a pea gravel diaphragm to slow the velocity and spread out the flow entering the basin, is the usual pretreatment method. The length of the grassed channel depends on the drainage area, land use, and channel slope. **Table 3.11-3** provides recommendations on sizing for grass channels leading into a bioretention basin for a one acre drainage area. The minimum grassed channel length should be 20 feet.

"Grassed filter strips, grassed channels, and side-slopes of the basin should be **sodded with mature sod** prior to placement of the bioretention basin into operation. Simply seeding these areas will likely result in conveyance of sediments into the basin and premature failure. Wrapping of the planting soil mixture up the side slopes beneath the sod is also recommended."

**TABLE 3.11-3**

***Pretreatment Grass Channel Sizing Guidance for a 1.0-Acre Drainage Area***

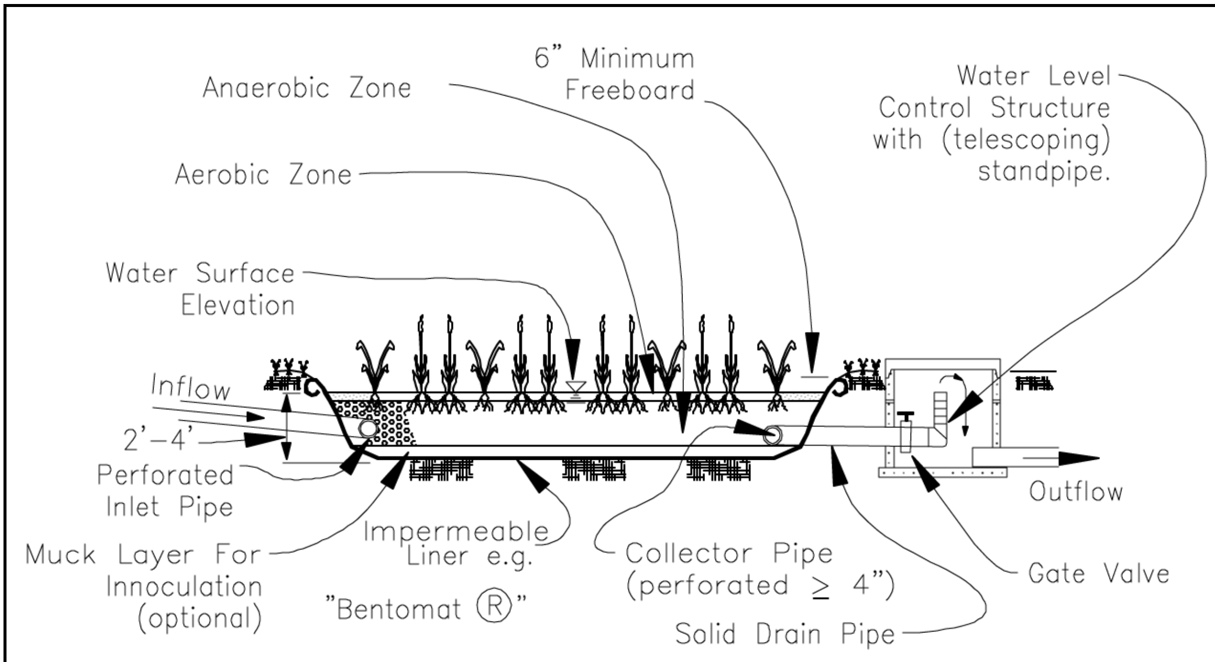
**(Source: Claytor and Schueler, 1996)**

| **Parameter** | **≤ 33% Impervious** | | **Between 34% and 66% Impervious** | | **≥ 67% Impervious** | | **Notes** |
|---|---|---|---|---|---|---|---|
| Slope | ≤2% | ≥2% | ≤2% | ≥2% | ≤2% | ≥2% | Maximum slope = 4% |
| Grassed channel minimum length (feet) | 25 | 40 | 30 | 45 | 35 | 50 | Assumes a 2' wide bottom width |

**FIGURE 3.11-6**

***Upflow Inlet for Bioretention Basin***

***(Source: City of Alexandria)***




When concentrated piped flow from impervious areas such as parking lots is routed to a bioretention basin, an energy absorbing and sedimentation structure in which the flow rises into the basin like a tide is usually advisable. Since sediments must usually be removed from such structures on a regular basis, they must be placed in locations where the extension booms on vacuum trucks may easily reach them. **Figure 3.11-6** illustrates an upflow inlet structure for a bioretention basin. Maintenance requirements for pretreatment measures are discussed **Maintenance/Inspection Guidelines**.

## General Design Criteria

The purpose of this section is to provide minimum criteria for the design of bioretention basin BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements. Bioretention basins which capture and infilter the first 1 inch of runoff from impervious surfaces may also provide streambank erosion protection.

### General

The design of bioretention basins should be in accordance with the following Minimum Standards where applicable: **3.1: Earthen Embankments, 3.2: Principal Spillways, 3.3: Vegetated Emergency Spillways, 3.4: Sediment Forebay, 3.10: General Infiltration Practices, and 3.10A: Infiltration Basin,** as well as the additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for the particular design but also for ensuring long-term operation.

### Soils Investigation

Refer to the **Planning Considerations** and **Design Criteria** of **General Infiltration Practices, MS-3.10**, and to local jurisdiction soil study requirements such as Chapter 5, Section V. of the ***Northern Virginia BMP Handbook***. As with infiltration basins (**MS3.10A**), a minimum of one soil boring log should be required for each 5,000 square feet of bioretention basin area (plan view area) and in no case less than three soil boring logs per basin.

### Topographic Conditions

Like other infiltration facilities, bioretention basins should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the impact of the basin upon the steep slope (especially in marine clay areas). Also, bioretention basins should be a minimum of 100 feet up-slope and 20 feet downslope from any buildings.

### Basin Sizing Methodology

In Virginia, bioretention basins are designed to exfilter the treatment quantity into the underlying soil strata, or into an underlying perforated underdrain system connected to a storm drain system or other outfall when the underlying soils, proximity to building foundation, or other such restrictions preclude the use of infiltration. When such an underdrain system is used, the facility is referred to as a **Bioretention Filter - Minimum Standard 3.11A**.

Recent research at the University of Maryland has supported a reduction in overall depth of the planting soil to 2.5 feet. Generally, the soil depth can be designed to a minimum depth equal to the diameter of the largest plant root ball plus 4 inches. The recommended soil composition was revised to reduce the clay and increase the sand content (Refer to Soil Texture and Structure later in this standard). This revised soil composition also eliminated the 12" sand layer at the bottom of the facility. The researchers concluded that significant pollutant reductions are achieved in the mulch layer and the first 2 to 2.5 feet of soil.

The elevation of the overflow structure should be 0.5 feet above the mulch layer of the bioretention bed. When an underdrain system is used (Min. Std. 3.11A), the overflow can be as much as 1.0 feet above the mulch layer.

The size of the bioretention facility is dictated by the amount of impervious surface in the contributing drainage area. For facilities capturing the first 0.5 inches of runoff from the impervious areas in the drainage shed, the surface area of the bioretention bed should be a minimum of 2.5% of the impervious area, or 1,090 square feet per impervious acre. For facilities capturing the first 1.0 inch of runoff, the bioretention bed should be a minimum of 5.0% of the impervious area, or 2,180 square feet per impervious acre.

The minimum width and length is recommended at 10 feet and 15 feet respectively. (Widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip).

The elevation of the overflow structure should be 0.5 feet above the mulch elevation of the bioretention bed.

**Note that small projects such as single family residences may default to the minimum (10' X 15') 150 square foot area.**

**TABLE 3.11-4**
***Basin Sizing Summary***

| **Treatment Volume** | **Basin Surface Area**<br>(Expressed as percentage of impervious area) |
|---|---|
| 0.5" per impervious acre | 2.5% |
| 1.0" per impervious acre | 5.0% |

Runoff Pretreatment

Like other infiltration basins, bioretention basins must always be preceded by a pretreatment facility to remove grease, oil, floatable organic material, and settleable solids (see Urban Runoff section of **Sediment Control** under **Planning Considerations** above). Where space constraints allow, runoff should be filtered by a grass buffer strip and sand bed. The buffer strip and sand bed will reduce the amount of fine material entering the bioretention area and minimize the potential for clogging of the planting soil. The sand bed also increases the infiltration capacity and provides aeration for the plant roots in the bioretention area. For basins for which high sediment loadings are expected (treating largely pervious areas, etc.), the design can be modified to include a sediment forebay (see **MS 3.04**). Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements.

Drainage Considerations

The grading design must shape the site so that all runoff from impervious areas is routed through the bioretention basins. The basins must be sited so as to accept the design runoff quantity before bypassing any excess flow to the storm drainage system. Bioretention basin locations must therefore be integrated into the basic site design from its inception. Most of the **Planning Considerations** delineated above must come into play at this early stage in the design process. The overall site and impervious surfaces must be contoured to direct the runoff to the basins. **Bioretention basins cannot usually be successfully integrated into a site design that does not take stormwater management into account from its inception.** Elevations must be carefully worked out to assure that the desired amount runoff will flow into the basins and pool at no more that the maximum design depth. This requires a much higher degree of vertical control during construction that is normal with most landscaping work.

Preferably, bioretention basins should be placed "off-line," i.e. the design should provide for runoff to be diverted into the basin until it fills with the treatment volume and then bypass the remaining flow around the BMP to the storm drainage system. The drainage system is normally designed to handle a specific storm event (the 10-year storm in most of Virginia). To prevent flood damage , however, the bioretention basin design must take into account how the runoff will be processed when larger events occur. This may require, at a minimum, that a vegetated emergency spillway be provided (see **MS-3.03**), and that a path for overland flow to an acceptable channel be incorporated into the design. The designer should provide for relief from the storm event specified by local development approval authority or for the 25-year storm event, whichever is the most stringent.

**Figure 3.11-2** illustrates an "off-line" application at the edge of a parking lot with curb and gutter. The inlet deflectors divert runoff into the bioretention basin until the basin fills and backs up. Subsequent runoff then bypasses to the adjacent, down gradient storm inlet. **Figure 3.11-3** illustrates an "off-line" application in a planting island in a parking lot, while **Figure 3.11-4** illustrates an "off-line application adjacent to a drainage swale (such highway drainage). Again, runoff flows into the bioretention basin until it fills, then bypasses down the swale. Placement of a flow diversion check dam in the swale will facilitate filling the basin. In some situations, an "off-line" configuration may not be practical or economical. Figure **3.11-1** and **3.11-5** illustrate applications where sheet flow enters the bioretention basin.

**Figure 3.11-7** illustrates a grading plan for a bioretention basin. The grading plan was created for a double-cell bioretention area. There is a seven-foot buffer between cells which allow for the planting of upland trees. As indicated in the grading plan, sheet and gutter flow is diverted into the bioretention areas through openings in the curb. The elevation of the invert of the bioretention area is set by the curb opening elevation. The curb opening elevation is 0.5 ft. higher than the invert of the bioretention area, so water is allowed to pond to a maximum depth of one-half foot before runoff bypasses the bioretention area and flows into the storm drain system.

Precise grading of the basin is critical to capturing the water quality volume and operation of the facility. The plan should have a contour interval of no more than one-foot, and spot elevations should be shown throughout the basin. The perimeter contour elevation should contain the design storm without over topping anywhere except at the outflow structure.

Exclusion of Continuous Flows and Chlorinated Flows

Bioretention and bioretention filter BMPs will **NOT** function properly if subjected to continuous or frequent flows. The basic principles upon which they operate assume that the sand filter will dry out and reaerate between storms. If the sand is kept continually wet by such flows as basement sump pumps, anaerobic conditions will develop, creating a situation under which previously captured iron phosphates degrade, leading to **export** of phosphates rather than the intended high phosphorous removal (Bell, Stokes, Gavan, and Nguyen, 1995). Anaerobic conditions will also kill most of the plants in the basin, stopping the biochemical pollutant removal processes and negating the aesthetic landscaping amenity aspects. It is also essential to **exclude flows containing chlorine and other swimming pool and sauna chemicals** since these will kill the bacteria upon which the principle nitrogen removal mechanisms depend.

***Continuous or frequent flows (such as basement sump pump discharges, cooling water, condensate water, artesian wells, etc.) and flows containing swimming pool and sauna chemicals MUST BE EXCLUDED from routing through bioretention or bioretention filter BMPs since such flows will cause the BMP to MALFUNCTION!***

Planting Plan

Selection of plantings must include coordination with overall site planning and aesthetic considerations for designing the bioretention plant community. Tables listing suitable species of trees, shrubs, and ground cover are provided at the end of this section. This listing is not intended to be all-inclusive due to the continual introduction of new horticultural varieties ans species in the nursery industry.

**1. Planting Concept**

The use of plantings in bioretention areas is modeled from the properties of a terrestrial forest community ecosystem. The terrestrial forest community ecosystem is an upland community dominated by trees, typically with a mature canopy, having a distinct sub-canopy of understory trees, a shrub layer, and herbaceous layer. In addition, the terrestrial forest ecosystem typically has a well-developed soil horizon with an organic layer and a mesic moisture regime. A terrestrial forest community model for stormwater management was selected based upon a forest's documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. These three elements are the major elements of the bioretention concept.

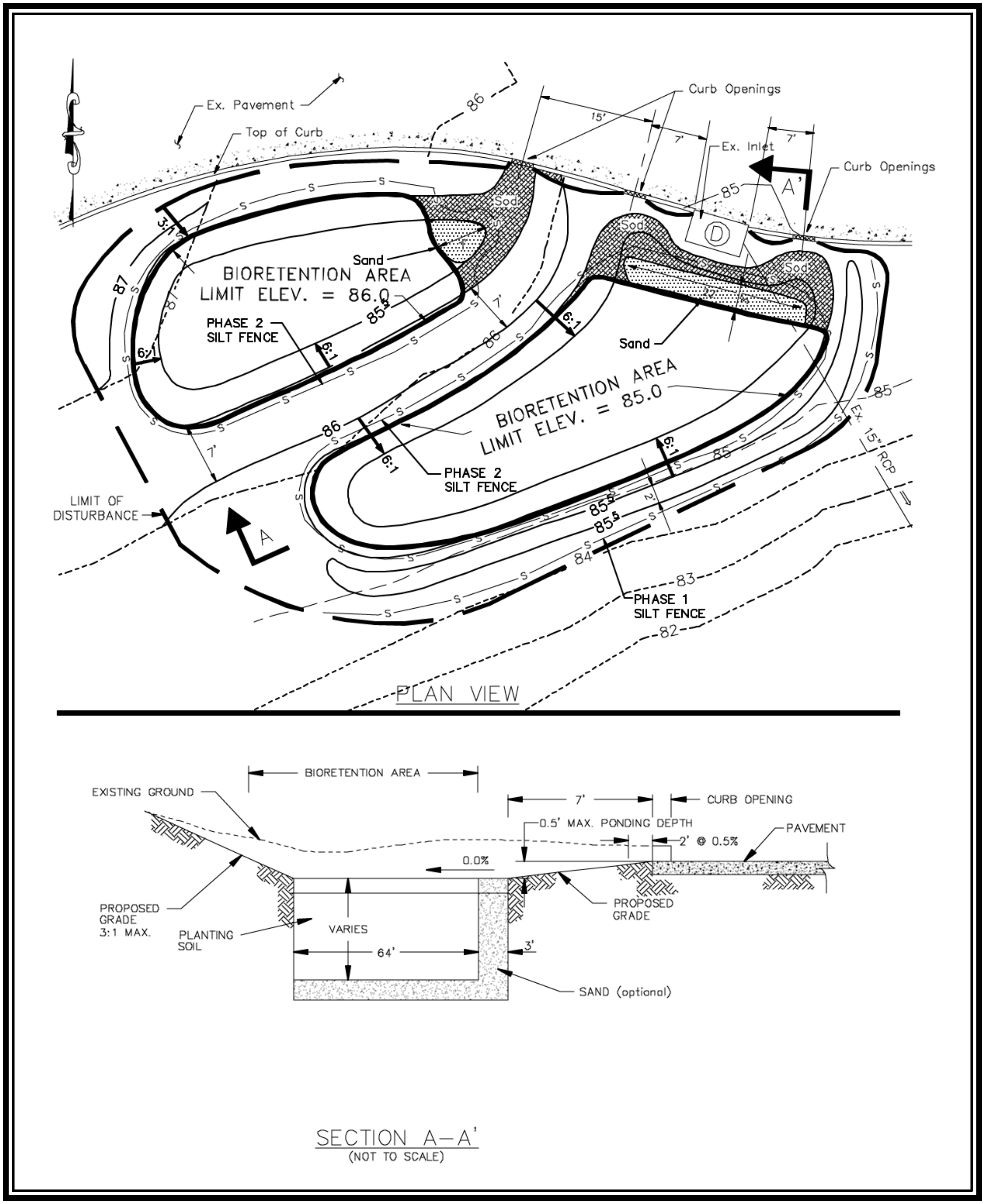
Key elements of the terrestrial forest ecosystem that have been incorporated into bioretention design include species diversity, density, and morphology, and use of native plant species. Species diversity protects the system against collapse from insect and disease infestations and other urban stresses such as temperature and exposure. Typically, indigenous plant species demonstrate a greater ability of adapting and tolerating physical, climatic, and biological stresses.

**2. Plant Species Selection**

Plant species appropriate for use in bioretention areas are presented in **Tables 3.11-7A** through **3.11-7C** , provided at the end of this section. These species have been selected based on the ability to tolerate urban stresses such as pollutants, variable soil moisture and ponding fluctuations. Important design considerations such as form, character, massing, texture, culture, growth habits/rates, maintenance requirements, hardiness, size, and type of root system are also included. A key factor in designating a species as suitable is its ability to tolerate the soil moisture regime and ponding fluctuations associated with bioretention. The plant indicator status (Reed, 1988) of listed species are predominantly facultative (i.e., they are adapted to stresses associated with both wet and dry conditions); however, facultative upland and wetland species have also been included. This is important because plants in bioretention areas will be exposed to varying levels of soil moisture and ponding throughout the year, ranging from high levels in the spring to potential drought conditions in the summer. All of the species listed in **Tables 3.11-7A - 3.11-7C** are commonly found growing in the Piedmont or Coastal Plain regions of Virginia as either native or ornamental species.

Recent research suggests an increase in the importance of the mulch layer and groundcover plant species in pollutant removal. The plant list in this standard will be expanded to include perennial flowering plants. A robust groundcover species with a thick mulch layer is recommended.

**FIGURE 3.11 - 7**
***Grading Plan for Bioretention Basin***



Designers considering species other than ones listed in **Tables 3.11-7A - 3.11-7C** should consult the following reference material on plant habitat requirements, and consider site conditions to ensure that alternative plant material will survive.

American Association of Nurserymen, Latest Edition. American Standard for Nursery Stock ASNI Z60, Washington, D.C.

Dirr, Michael A., 1975. Manual of Woody Landscape Plants, Stripes Publishing Company, Champagne, Illinois.

Hightshoe, G.L., 1988. Native Trees, Shrubs, and Vines for Urban and Rural America. Van Nostrand Reinhold, New York, New York.

Reed, P.B.Jr., 1988. National List of Species That Occur in Wetlands: Northeast. United States Fish and Wildlife Service, St. Petersburg Florida.

Reasons for exclusion of certain plants from bioretention areas include inability to meet the criteria outlined in **Tables 3.11-7A - 3.11-7C** (pollutant and metals tolerance, soil moisture and structure, ponding fluctuations, morphology, etc.). In addition, species that are considered invasive or not recommended by the Urban Design Section of the Maryland-National Capital Park and Planning Commission are not recommended (Prince George's County, 1989).

### 3. Site and Ecological Considerations

Each site is unique and may contain factors that should be considered before selecting plant species. An example **Plant Material Checklist** is provided in **Appendix 3E**. The checklist has been developed to assist the designer in identifying critical factors about a site that may affect both the plant material layout and the species selection.

Selection of plant species should also be based on site conditions and ecological factors. Site considerations include microclimate (light, temperature, wind), the importance of aesthetics, overall site development design and the extent of maintenance requirements, and proposed or existing buildings . Of particular concern is the increase in reflection of solar radiation from buildings upon bioretention areas. Aesthetics are critical in projects of high visibility. Species that require regular maintenance (shed fruit or are prone to storm damage) should be restricted to areas of limited visibility and pedestrian and vehicular traffic.

Interactions with adjacent plant communities are also critical. Nearby existing vegetated areas dominated by non-native invasive species pose a threat to adjacent bioretention areas. Proposed bioretention area species should be evaluated for compatibility with adjacent plant communities. Invasive species typically develop into monocultures by out competing other species . Mechanisms to avoid encroachment of undesirable species include increased maintenance, providing a soil breach between the invasive community for those species that spread through rhizomes, and providing annual removal of seedlings from wind borne seed dispersal. Existing disease or insect infestations associated with existing site conditions or in the general area that may effect the bioretention plantings.

### 4. Number of Species

A minimum of three species of trees and three species of shrubs should be selected to insure diversity. In addition to reducing the potential for monoculture mortality concerns, a diversity of trees and shrubs with differing rates of transpiration may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.

Herbaceous ground covers are important to prevent erosion of the mulch and the soil layers. Suitable herbaceous ground covers are identified in **Table 3.11-7C**.

### 5. Number and Size of Plants

The requisite number of plantings varies, and should be determined on an individual site basis. On average, 1000 trees and shrubs should be planted per acre. For example, a bioretention area measuring 15' x 40' would contain a combination of trees and shrubs totaling 14 individuals. The Prince Georges County recommended minimum and maximum number of individual plants and spacing are given in **Table 3.11-4.** Virginia jurisdictions with significant experience with bioretention prefer the simpler specification of 10 trees and shrubs per 1,000 square feet of basin area, with placement specified by a landscape professional to simulate natural conditions. Two to three shrubs should be specified for each tree (2:1 to 3:1 ratio of shrubs to trees).

At installation, trees should be 1.0 inches minimum in caliper, and shrubs 3 to 4 feet in height or 18 to 24 inches in spread per ASNI Z60. Ground cover may be as seed or, preferably, plugs. The relatively mature size requirements for trees and shrubs are important to ensure that the installation of plants are readily contributing to the bioretention process (i.e., evapotranspiration, pollutant uptake).

**TABLE 3.11-5**
***Recommended Tree and Shrub Spacing***

| | Tree Spacing (feet) | Shrub Spacing (feet) | Total Density (stems/acre) |
|---|---|---|---|
| Maximum | 19 | 12 | 400 |
| Average | 12 | 8 | 1000 |
| Minimum | 11 | 7 | 1250 |

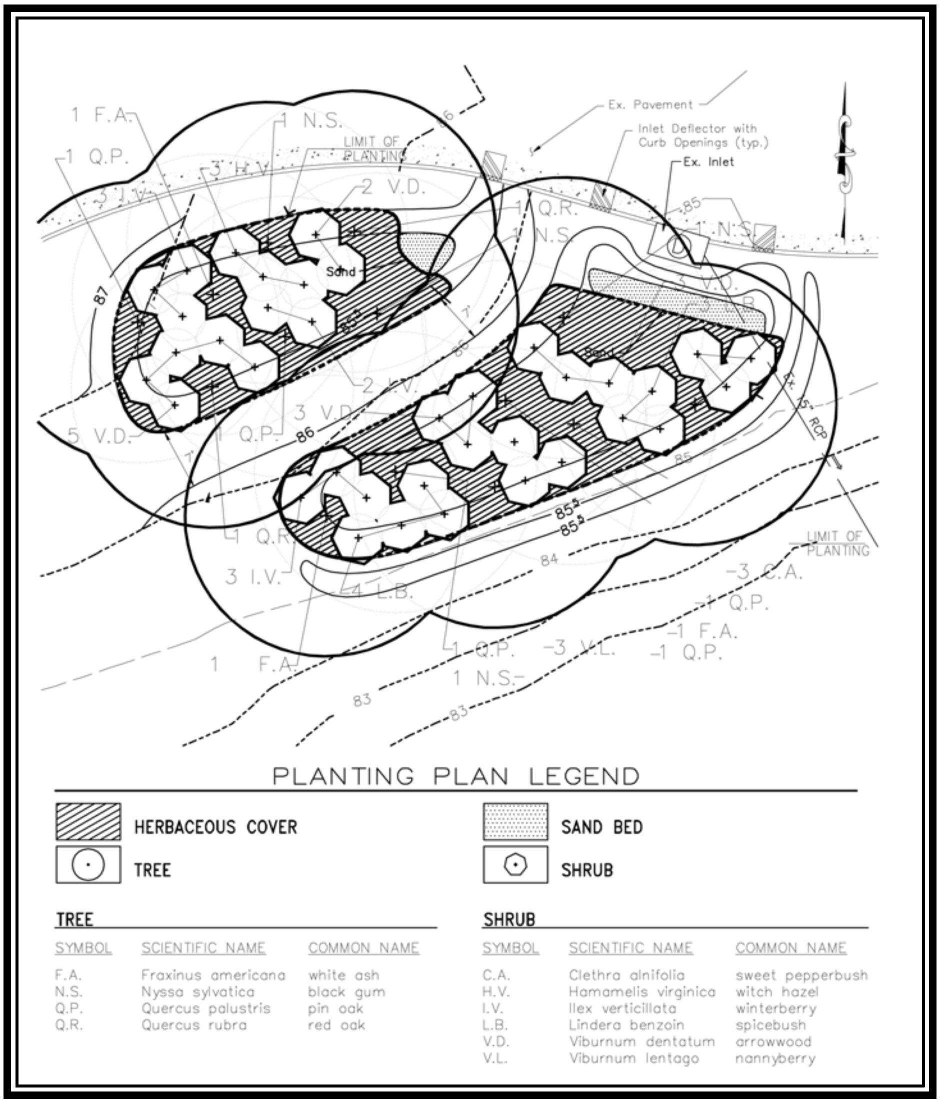
### 6. Plant Layout

The layout of plant material can be a flexible process; however, the designer should follow some basic guidelines. As discussed above, the designer should first review the Plant Checklist (Appendix D). The checklist table can help expose any constraints that may limit the use of a particular species and/or where a species can be installed.

There are two guidelines that should apply to all bioretention areas. First, woody plant material should not be placed within the immediate areas of where flow will be entering the bioretention area.

Besides possibly concentrating flows, trees and shrubs can be damaged as a result of the flow. Secondly, it is recommended that trees be planted primarily on the perimeter of bioretention areas, to maximize the shading and sheltering of bioretention areas to create a microclimate which will limit the extreme exposure from summer solar radiation and winter freezes and winds. An example planting plan is shown in **Figure 3.11-8**.

**FIGURE 3.11 - 8**
***Sample Planting Plan***




Planting Soil Guidelines

The characteristics of the soil play an important role in the improvement of water quality through the use of bioretention systems. The soil is a three-phase system composed of gas, liquid, and solid, each of which in the proper balance is essential to the pollutant removal achieved through bioretention. The soil anchors the plants and provides nutrients and moisture for plant growth. Microorganisms inhabit and proliferate within the soil solution, and the unsaturated pore space provides plant roots with the oxygen necessary for metabolism and growth.

A desirable planting soil would 1) be permeable to allow infiltration of runoff and 2) provide adsorption of organic nitrogen and phosphorus.

The recommended planting soil for bioretention would have the following properties:

**1. Soil Texture and Structure**

It is recommended that the planting soils for bioretention have a sandy loam, loamy sand, or loam texture. Experience in both Maryland and Virginia has indicated that the original soil specification contained in the Prince Georges County manual must be modified to decrease the clay content to **no more than five percent** to preclude premature failure of the basins due to clogging. Prince Georges County issued a design update in June 1998 in which the total depth of the facility is reduced to 2.5 feet by the elimination of the sand bed and the use of a soil media consisting of 50 percent sand, 20 percent leaf compost, and 30 percent topsoil. Virginia engineers with bioretention experience recommend using either the new Maryland media specification or a media of 50 percent sand and 50 percent hemic or fibric peat, using the Virginia topsoil thickness criteria in both cases, while retaining the sand bed. This could result in an overall thickness somewhat comparable to that specified in Maryland.

**2. Soil Acidity**

In a bioretention scheme, the desired soil pH would lie between 5.5 and 6.5 (Tisdale and Nelson, 1975). The soil acidity affects the ability of the soil to adsorb and desorb nutrients, and also affects the microbiological activity in the soil.

**3. Soil Testing**

The planting soil for bioretention areas must be tested prior to installation for pH, organic matter, and other chemical constituents. The soil should meet the following criteria (Landscape Contractors Association, 4th Addition, 1993):

| | |
|---|---|
| pH range: | 5.0 - 7.0 |
| Organic matter: | Greater than 1.5 |
| Magnesium (Mg): | 100+ Units |
| Phosphorus ($P_2O_5$): | 150+ Units |
| Potassium ($K_2O$): | 120+ Units |
| Soluble salts: | not to exceed 900 ppm/.9 MMHOS/cm (soil) |
| | not to exceed 3,000 ppm/2.5 MMHOS/cm (organic mix) |

It is recommended that one test for magnesium, phosphorus, potassium, and soluble salts be performed per borrow source or for every 500 cubic yards of soil material. It is recommended that a sieve analysis, pH, and organic matter test be performed per bioretention area.

**4. Soil Placement**

Placement of the planting soil in the bioretention area should be in lifts of 18 inches or less and lightly compacted. Minimal compaction effort can be applied to the soil by tamping.

Specifications for the planting soil are outlined below under **Construction Specifications**.

<u>Mulch Layer Guidelines</u>

Recent results of bioretention monitoring in Maryland has confirmed that the mulch layer plays a crucial role in the pollutant removal capabilities of the facility. This layer serves to prevent erosion and to protect the soil from excessive drying. Soil biota existing within the organic and soil layer are important in the filtering of nutrients and pollutants and assisting in maintaining soil fertility. Bioretention areas can be designed either with or without a mulch layer. If a herbaceous layer or ground cover (70 to 80% coverage) is provided, a mulch layer is not necessary. Areas should be mulched once trees and shrubs have been planted. Any ground cover specified as plugs may be installed once mulch has been applied.

The mulch layer recommended for bioretention may consist of either a standard landscape fine shredded hardwood mulch or shredded hardwood chips. Both types of mulch are commercially available and provide excellent protection from erosion.

Mulch shall be free of weed seeds, soil, roots, or any other substance not consisting of either bole or branch wood and bark. The mulch shall be uniformly applied approximately 2 to 3 inches in depth. Mulch applied any deeper than three inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere.

Grass clippings are unsuitable for mulch, primarily due to the excessive quantities of nitrogen built up in the material. Adding large sources of nitrogen would limit the capability of bioretention areas to filter the nitrogen associated with runoff.

<u>Plant Material Guidelines</u>

**1. Plant Material Source**

The plant material should conform to the current issue of the <u>American Standard for Nursery Stock</u> published by the American Association of Nurserymen. Plant material should be selected from certified nurseries that have been inspected by state or federal agencies. The botanical (scientific) name of the plant species should be in accordance with a standard nomenclature source such as Birr, 1975.

Some of the plant species listed in **Tables 3.11-7A - 3.11-7C**, Recommended Plant Species For Use in Bioretention may be unavailable from standard nursery sources. These are typically species native to Virginia and may not be commonly used in standard practices. Designers may need to contact nurseries specializing in native plants propagation.

## 2. Installation

The success of bioretention areas is dependent on the proper installation specifications that are developed by the designer and subsequently followed by the contractor. The specifications include the procedures for installing the plants and the necessary steps taken before and after installation. Specifications designed for bioretention should include the following considerations:

- Sequence of Construction
- Contractors Responsibilities
- Planting Schedule and Specifications
- Maintenance
- Warranty

The sequence of construction describes site preparation activities such as grading, soil amendments, and any pre-planting structure installation. It also should address erosion and sediment control procedures. Erosion and sediment control practices should be in place until the entire bioretention area is completed. The contractors responsibilities should include all the specifications that directly effect the contractor in the performance of his or her work. The responsibilities include any penalties for unnecessarily delayed work, requests for changes to the design or contract, and exclusions from the contract specifications such as vandalism to the site, etc.

The planting schedule and specifications include type of material to be installed (e.g., ball and burlap, bare root, or containerized material), timing of installation, and post installation procedures. Balled and burlapped and containerized trees and shrubs should be planted during the following periods: March 15 through June 30 and September 15 through November 15. Ground cover excluding grasses and legumes can follow tree and shrub planting dates. Grasses and legumes typically should be planted in the spring of the year. The planting of trees and shrubs should be performed by following the planting specifications set forth in **MS 3.05, Landscaping. MS 3.05** specifications provide guidelines that insure the proper placement and installation of plant material. Designers may choose to use other specifications or to modify the jurisdiction specifications. However, any deviations from the jurisdiction specifications need to address the following:

- transport of plant material
- preparation of the planting pit
- installation of plant material
- stabilization seeding (if applicable)
- maintenance

An example of general planting specification for trees and shrubs and ground cover is given under **Construction Specifications** below.

### 3. Warranties

Typically, a warranty is established as a part of any plant installation project. The warranty covers all components of the installation that the contractor is responsible for. The plant and mulch installation for bioretention should be performed by a professional landscape contractor. An example of standard guidelines for landscape contract work is provided below:

- The contractor shall maintain a one (1) calendar year 80% care and replacement warranty for all planting.
- The period of care and replacement shall begin after inspection and approval of the complete installation of all plants and continue for one calendar year.
- Plant replacements shall be in accordance with the maintenance schedule.

Plant Growth and Soil Fertility

A discussion of plant growth and soil fertility development over time is important to for estimating the success and lifespan of bioretention areas. The physical, chemical, and biological factors influencing plant growth and development will vary over time as well as for each bioretention area. However, there are certain plant and soil processes that will be the same for all bioretention areas.

### 1. Plant Growth

The role of plants in bioretention includes uptake of nutrients and pollutants and evapotranspiration of stormwater runoff. The plant material, especially ground covers, are expected to contribute to the evapotranspiration process within the first year of planting. However, trees and shrubs that have been recently planted demonstrate slower rates of growth for the first season due to the initial shock of transplanting. The relative rate of growth is expected to increase to normal rates after the second growth season.

The growth rate for plants in bioretention areas will follow a similar pattern to that of other tree and shrub plantings (reforestation projects, landscaping). For the first two years, the majority of tree and shrub growth occurs with the expansion of the plant root system. By the third or fourth year the growth of the stem and branch system dominates increasing the height and width of the plant. The comparative rate of growth between the root and stem and branch system remains relatively the same throughout the lifespan of the plant. The reproductive system (flowers, fruit) of the plants is initiated last.

The growth rates and time for ground covers to become acclimated to bioretention conditions is much faster than for trees and shrubs. The rate of growth of a typical ground cover can often exceed 100 percent in the first year. Ground covers are considered essentially mature after the first year of growth. The longevity of ground covers will be influenced by the soil fertility and chemistry as well as physical factors, such as shading and overcrowding from trees and shrubs and other ecological and physical factors.

Plants are expected to increase their contribution to the bioretention concept over time, assuming that growing conditions are suitable. The rate of plant growth is directly proportional to the environment in which the plant is established. Plants grown in optimal environments experience greater rates of growth. One of the primary factors determining this is soil fertility.

### 2. Soil Fertility

Initially, soil in bioretention areas will lack a mature soil profile. It is expected that over time discrete soil zones referred to as horizons will develop. The development of a soil profile and the individual horizons is determined by the influence of the surrounding environment including physical, chemical, and biological processes. Two primary processes important to horizon development is microbial action and the percolation of runoff in the soil.

Horizons expected to develop in bioretention areas include an organic layer, followed by two horizons where active leaching (eluviation) and accumulation (illuvation) of minerals and other substances occur. The time frame for the development of soil horizons will vary greatly. As an average, soil horizons may develop within three to ten years. The exception to this is the formation of the organic layer often within the first or second year (Brady, 1984).

The evaluation of soil fertility in bioretention may be more dependent on the soil interactions relative to plant growth than horizon development. The soil specified for bioretention is important in filtering pollutants and nutrients as well as supply plants with water, nutrients, and support. Unlike plants that will become increasingly beneficial over time, the soil will begin to filter the storm water runoff immediately. It is expected that the ability to filter pollutants and nutrients may decrease over time, reducing the soil fertility accordingly. Substances from runoff such as salt and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC, the ability to allow for binding of particles by ion attraction, decreases to the point that the transfer of nutrients for plant uptake can not occur. However, the environmental factors influencing each bioretention area will vary enough that it is difficult to predict for the lifespan of soils. Findings from other stormwater management systems suggest an accumulation of substances eliminating soil fertility within five years. The monitoring of soil development in bioretention areas will help develop better predictions on soil fertility and development.

## Construction Specifications

The construction of bioretention basins should be in accordance with the following Minimum Specifications and Standards where applicable: **3.1: Earthen Embankments; 3.2: Principal Spillways; 3.3: Vegetated Emergency Spillways; 3.4: Sediment Forebays; 3.5: Landscaping; 3.10: General Infiltration Practices**, as well as the additional criteria set forth below. These specifications have been adapted from the Prince George's County, Maryland publication, ***Design Manual for Use of Bioretention in Stormwater Management***.

Sequence of Construction

The sequence of various phases of basin construction must be coordinated with the overall project construction. As with other infiltration practices, rough excavation of the basin may be scheduled with the rough grading of the project to permit use of the excavated material as fill elsewhere on the site. However, the bioretention basin must not be constructed or placed in service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may otherwise load the newly formed basin with a large load of fine sediment, seriously impairing the natural infiltration ability of the basin floor. For these reasons, **the locations of infiltration bioretention basins must NOT be used for sediment basins for erosion and sediment protection during site construction.** The sequence of construction shall be as follows:

1. Install Phase I erosion and sediment control measures for the site.

2. Grade each site to elevations shown on plan. Initially, the basin floor may be excavated to within one foot of its final elevation. Excavation to finished grade shall be deferred until all disturbed areas within the watershed have been stabilized and protected. Construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area.

3. Complete construction on the watershed and stabilize all areas draining to the Bioretention basin.

4. Remove Phase I sediment control devices at direction of designated inspector.

5. Install Phase II erosion and sediment control measures for bioretention area.

6. Remove all accumulated sediment and excavate Bioretention Area to proposed depth. Use relatively light, tracked equipment to avoid compaction of the basin floor. After final grading is completed, deeply till the basin floor with rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

7. Install the infiltration chambers, piping, manifolds, drains, vents, and infiltration stone in accordance in with the specifications and directions of the chamber manufacturer. Install a six-inch layer of washed, 1/4-inch pea gravel above the stone. Install a 1-foot layer of ASTM C-33 concrete sand on top of the pea gravel. Lightly compact with a landscaping roller.

8. After confirmation that soil meets specs by performing the requisite gradation and chemical tests (see below), fill Bioretention Area with planting soil and sand, as shown in the plans and detailed in the specifications.

9. Install vegetation and ground cover specified in the planting plan for Bioretention Area.

Install mulch layer if called for in the design.

10. Place sod, EC fabric, or non erosive lining (depending on inflow velocities) in the inlet channel and/or filter strips.

11. Upon authorization from designated inspector, remove all sediment controls and stabilize all disturbed areas. Unblock curb openings, and provide drainage to the Bioretention Areas.

Bioretention Area Soil Specifications

**1. Planting Soil**

The bioretention areas shall contain a planting soil mixture of 50% sand, 30% leaf compost (fully composted, NOT partially rotted leaves), and 20% topsoil. Topsoil shall be sandy loam or loamy sand of uniform composition, containing no more than 5% clay, free of stones, stumps, roots, or similar objects greater than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to plant growth or maintenance.

The top soil shall be free of plants or plant parts of Bermuda grass, Quack grass, Johnson grass, Mugwort, Nutsedge, Poison Ivy, Canadian Thistle or others as specified. It shall not contain toxic substances harmful to plant growth.

The top soil shall be tested and meet the following criteria:

| | |
|---|---|
| pH range: | 5.0 - 7.0 |
| Organic matter: | Greater than 1.5 |
| Magnesium (Mg): | 100+ Units |
| Phosphorus ($P_2O_5$): | 150+ Units |
| Potassium ($K_2O$): | 120+ Units |
| Soluble salts: | not to exceed 900 ppm/.9 MMHOS/cm (soil)<br>not to exceed 3,000 ppm/2.5 MMHOS/cm (organic mix) |

The following testing frequencies shall apply to the above soil constituents:

pH, Organic Matter: 1 test per 90 cubic yards, but no more than 1 test per Bioretention Area

Magnesium, Phosphorus, Potassium, Soluble Salts:

1 test per 500 cubic yards, but no less than 1 test per borrow source

One grain size analysis shall per performed per 90 cubic yards of planting soil, but no less than 1 test per Bioretention Area. Soil tests must be verified by a qualified professional.

**2. Mulch**

A mulch layer shall be provided on top of the planting soil. An acceptable mulch layer shall include shredded hardwood or shredded wood chips or other similar product.

Of the approved mulch products all must be well aged, uniform in color, and free of foreign material including plant material.

**3. Sand**

The sand for bioretention basins when utilized, shall be ASTM C-33 Concrete Sand and free of deleterious material.

**4. Compaction**

Soil shall be placed in lifts less than 18 inches and lightly compacted (minimal compactive effort) by tamping or rolled with a hand-operated landscape roller.

<u>Bioretention Area Planting Specifications</u>

1. Root stock of the plant material shall be kept moist during transport from the source to the job site and until planted.

2. Walls of planting pit shall be dug so that they are vertical.

3. The diameter of the planting pit must be a minimum of six inches (6") larger than the diameter of the ball of the tree.

4. The planting pit shall be deep enough to allow 1/8 of the overall dimension of the root ball to be above grade. Loose soil at the bottom of the pit shall be tamped by hand.

5. The appropriate amount of fertilizer is to be placed at the bottom of the pit (see below for fertilization rates).

6. The plant shall be removed from the container and placed in the planting pit by lifting and carrying the plant by its' ball (never lift by branches or trunk).

7. Set the plant straight and in the center of the pit so that approximately 1/8 of the diameter of the root ball is above the final grade.

8. Backfill planting pit with existing soil.

9. Make sure plant remains straight during backfilling procedure.

10. Never cover the top of the ball with soil. Mound soil around the exposed ball.

11. Trees shall be braced by using 2" by 2" white oak stakes. Stakes shall be placed parallel to walkways and buildings. Stakes are to be equally spaced on the outside of the tree ball. Utilizing hose and wire the tree is braced to the stakes.

12. Because of the high levels of nutrients in stormwater runoff to be treated, bioretention basin plants should not require chemical fertilization.

## Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific Facilities may require additional measures not discussed here.

A schedule of recommended maintenance for bioretention areas is given in **Table 3.11-5**. The table gives general guidance regarding methods, frequency, and time of year for maintenance.

Planting Soil

Urban plant communities tend to become very acidic due to precipitation as well as the influences of storm water runoff. For this reason, it is recommended that the application of alkaline, such as limestone, be considered once to twice a year. Testing of the pH of the organic layer and soil, should precede the limestone application to determine the amount of limestone required.

Soil testing should be conducted annually so that the accumulation of toxins and heavy metals can be detected or prevented. Over a period of time, heavy metals and other toxic substances will tend to accumulate in the soil and the plants. Data from other environs such as forest buffers and grass swales suggest accumulation of toxins and heavy metals within five years of installation. However, there is no methodology to estimate the level of toxic materials in the bioretention areas since runoff, soil, and plant characteristics will vary from site to site.

As the toxic substances accumulate, the plant biologic functions may become impaired, and the plant may experience dwarfed growth followed by mortality. The biota within the soil can also become void and the natural soil chemistry may be altered. The preventative measures would include the removal of the contaminated soil. In some cases, removal and disposal of the entire soil base as well as the plant material may be required.

Mulch

Bioretention areas should be mulched once the planting of trees and shrubs has occurred. Any ground cover specified as plugs may be installed once the area has been mulched. Ground cover established by seeding and\or consisting of grass should not be covered with mulch.

Plant Materials

An important aspect of landscape architecture is to design areas that require little maintenance. Certain plant species involve maintenance problems due to dropping of fruit or other portions of the plant. Another problem includes plants, primarily trees, that are susceptible to windthrow, which creates a potential hazard to people and property (parked cars). As a result, some plant species will be limited to use in low-traffic areas.

Ongoing monitoring and maintenance is vital to the overall success of bioretention areas. Annual maintenance will be required for plant material, mulch layer, and soil layer. A maintenance schedule should include all of the main considerations discussed below. The maintenance schedule usually includes maintenance as part of the construction phase of the project and for life of the design. A example maintenance schedule is shown in **Table 3.11-6**.

Maintenance requirements will vary depending on the importance of aesthetics. Soil and mulch layer maintenance will be most likely limited to correcting areas of erosion. Replacement of mulch layers may be necessary every two to three years. Mulch should be replaced in the spring. When the mulch layer is replaced, the previous layer should be removed first. Plant material upkeep will include addressing problems associated with disease or insect infestations, replacing dead plant material, and any necessary pruning.

Control of Sediments on the Drainage Shed

Care must be taken to protect the bioretention basin from excessive sediments from the drainage shed. Whenever additional land disturbing activity takes place in the area draining to the basin, effective erosion and sediment control measures must first be put in place to exclude sediments from the basin. Performance based special measures over and above those specified in the ***Virginia Erosion and Sediment Control Handbook***, latest edition, may be required to assure that the bioretention basin is not damaged by such land disturbance. When sand or other street abrasives are used during the snow or icing conditions to provide traction on roadways or parking lots draining to bioretention basins, the pavement should be power/vacuum swept as soon as freezing weather abates to prevent damage to the basins.

## Checklists

The Construction Inspection and As-Built Checklist provided in **Appendix 3E** is for use in inspecting bioretention basins during construction, and where required by local jurisdiction, engineering certification of the basin construction. The Operation and Maintenance Inspection Checklist, also found in **Appendix 3E**, is for use in conducting maintenance inspections of bioretention basins.

**TABLE 3.11 - 6**
***Example Maintenance Schedule for Bioretention Basin***

| Description | Method | Frequency | Time of the year |
|---|---|---|---|
| SOIL | | | |
| Inspect and Repair Erosion | Visual | Monthly | Monthly |
| ORGANIC LAYER | | | |
| Remulch any void areas | By hand | Whenever needed | Whenever needed |
| Remove previous mulch layer before applying new layer (optional) | By hand | Once every two to three years | Spring |
| Any additional mulch added (optional) | By hand | Once a year | Spring |
| PLANTS | | | |
| Removal and replacement of all dead and diseased vegetation considered beyond treatment | See planting specifications | Twice a year | 3/15 to 4/30 and 10/1 to 11/30 |
| Treat all diseased trees and shrubs | Mechanical or by hand | N/A | Varies, depends on insect or disease infestation |
| Watering of plant material shall take place at the end of each day for fourteen consecutive days after planting has been completed | By hand | Immediately after completion of project | N/A |
| Replace stakes after one year | By hand | Once a year | Only remove stakes In the spring |
| Replace any deficient stakes or wires | By hand | N/A | Whenever needed |
| Check for accumulated sediments | Visual | Monthly | Monthly |

## TABLE 3.11-7A RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name*<br>Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Acer rubrum*<br>red maple | FAC | Mesic - Hydric | 4-6 | H | H | H | H | Partial Sun | Single to multi-stem tree | 50-70' | Shallow | Yes | - | High | - |
| *Amelanchier canadensis*<br>shadbush | FAC | Mesic | 2-4 | H | M | - | H | Partial Sun | Single to multi-stem tree | 35-50' | Shallow | Yes | - | High | Not recommended for full sun. |
| *Betula nigra*<br>river birch | FACW | Mesic - Hydric | 4-6 | - | M | M | H | Partial Sun | Single to multi-stem tree | 50-75' | Shallow | Yes | - | High | Not susceptible to bronze birch borer. |
| *Betula populifolia*<br>gray birch | FAC | Xeric - Hydric | 4-6 | H | H | M | H | Partial Sun | Single to multi-stem tree | 35-50' | Shallow to deep | - | Yes | High | Native to New England area. |
| *Fraxinus americana*<br>white ash | FAC | Mesic | 2-4 | M | H | H | H | Sun | Large tree | 50-80' | Deep | Yes | - | Low | - |
| *Fraxinus pennsylvanica*<br>green ash | FACW | Mesic | 4-6 | M | H | H | H | Partial Sun | Large tree | 40-65' | Shallow to deep | Yes | - | Low | - |
| *Ginkgo biloba*<br>Maidenhair tree | FAC | Mesic | 2-4 | H | H | H | H | Sun | Large tree | 50-80' | Shallow to deep | - | Yes | Low | Avoid female species-offensive odor from fruit. |
| *Gleditsia triacanthos*<br>honeylocust | FAC | Mesic | 2-4 | H | M | - | M | Sun | Small canopied large tree | 50-75' | Shallow to deep variable taproot | Yes | - | Low | Select thornless variety. |
| *Juniperus virginiana*<br>eastern red cedar | FACU | Mesic - Xeric | 2-4 | H | H | - | H | Sun | Dense single stem tree | 50-75' | Taproot | Yes | - | Very High | Evergreen |
| *Koelreuteria paniculata*<br>golden-rain tree | FACU | Mesic | 2-4 | H | H | H | H | Sun | Round, dense shade tree | 20-30' | Shallow | - | Yes | No | - |
| *Liquidambar styraciflua*<br>sweet gum | FAC | Mesic | 4-6 | H | H | H | M | Sun | Large tree | 50-70' | Deep taproot | Yes | - | High | Edge and perimeter; fruit is a maintenance problem. |
| *Nyssa sylvatica*<br>black gum | FACW | Mesic - Hydric | 4-6 | H | H | H | H | Sun | Large tree | 40-70' | Shallow to deep taproot | Yes | - | High | - |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

**NOTE:** Heights shown in table are under ideal conditions in rural settings. They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

## TABLE 3.11-7A  RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name*<br>Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Platanus acerifolia*<br>London plane-tree | FACW | Mesic | 2-4 | H | - | - | M | Sun | Large tree | 70-80' | Shallow | - | Yes | Low | Tree roots can heave sidewalks. |
| *Platanus occidentalis*<br>sycamore | FACW | Mesic - Hydric | 4-6 | M | M | M | M | Sun | Large tree | 70-80' | Shallow | Yes | - | Med. | Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow. |
| *Populus deltoides*<br>eastern cottonwood | FAC | Xeric - Mesic | 4-6 | H | H | H | L | Sun | Large tree with spreading branches | 75-100' | Shallow | Yes | - | High | Short lived. |
| *Quercus bicolor*<br>swamp white oak | FACW | Mesic to wet Mesic | 4-6 | H | - | H | H | Sun to partial sun | Large tree | 75-100' | Shallow | Yes | - | High | One of the faster growing oaks. |
| *Quercus coccinea*<br>scarlet oak | FAC | Mesic | 1-2 | H | M | M | M | Sun | Large tree | 50-75' | Shallow to deep | Yes | - | High | - |
| *Quercus macrocarpa*<br>bur oak | FAC | Mesic to wet Mesic | 2-4 | H | H | H | M | Sun | Large spreading tree | 75-100' | Taproot | - | Yes | High | Native to midwest. |
| *Quercus palustris*<br>pin oak | FACW | Mesic - Hydric | 4-6 | H | H | H | M | Sun | Large tree | 60-80' | Shallow to deep taproot | Yes | - | High | - |
| *Quercus phellos*<br>willow oak | FACW | Mesic to wet Mesic | 4-6 | H | - | - | H | Sun | Large tree | 55-75' | Shallow | Yes | - | High | Fast growing oak. |
| *Quercus rubra*<br>red oak | FAC | Mesic | 2-4 | M | H | M | M | Sun to partial sun | Large spreading tree | 60-80' | Deep taproot | Yes | - | High | - |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

**NOTE:** Heights shown in table are under ideal conditions in rural settings.  They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

## TABLE 3.11-7A RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name*<br>Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Robinia pseudo-acacia*<br>black locust | FAC | Mesic - Xeric | 2-4 | H | H | H | M | Sun | Typically tall and slender | 30-50' | Shallow | Yes | - | Low | Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow. |
| *Sophora japonica*<br>Japanese pagoda tree | FAC | Mesic | 1-2 | M | M | - | M | Sun | Shade tree | 40-70' | Shallow | - | Yes | Low | Fruit stains sidewalks etc. |
| *Taxodium distichum*<br>bald cypress | FACW | Mesic - Hydric | 4-6 | - | - | M | H | Sun to partial sun | Typically single stem tree | 75-100' | Shallow | Yes | - | Low | Not well documented for planting in urban areas. |
| *Zelkova serrata*<br>Japanese zelkova | FACU | Mesic | 1-2 | M | M | - | H | Sun | Dense shade tree | 60-70' | Shallow | - | Yes | Low | Branches can split easily in storms. |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

**NOTE:** Heights shown in table are under ideal conditions in rural settings. They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

## TABLE 3.11-7B RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- SHRUB SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name* Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Berberis koreana* barberry | FAC | Mesic | 2-4 | H | H | H | M | Sun to partial sun | Oval shrub | 4-6' | Shallow | - | Yes | Low | - |
| *Berberis thunbergii* Japanese barberry | FAC | Mesic | 2-4 | H | H | H | M | Sun | Rounded, broad dense shrub | 5-7' | Shallow | - | Yes | Med. | - |
| *Clethra alnifolia* sweet pepperbush | FAC | Mesic to wet Mesic | 2-4 | H | - | - | H | Sun to partial sun | Ovoid shrub | 6-12' | Shallow | Yes | - | Med. | Coastal plain species |
| *Cornus Stolonifera* red osier dogwood | FACW | Mesic - Hydric | 2-4 | H | H | H | M | Sun or shade | Arching, spreading shrub | 8-10' | Shallow | Yes | - | High | Needs more consistant moisture levels. |
| *Euonymus alatus* winged euonymous | FAC | Mesic | 1-2 | H | H | H | M | Sun or shade | Flat, dense horizontal branching shrub | 5-7' | Shallow | - | Yes | No | - |
| *Euonymus europaeus* spindle-tree | FAC | Mesic | 1-2 | M | M | M | M | Sun to partial sun | Upright dense oval shrub | 10-12' | Shallow | - | Yes | No | - |
| *Hamamelis virginiana* witch-hazel | FAC | Mesic | 2-4 | M | M | M | M | Sun or shade | Vase-like compact shrub | 4-6' | Shallow | Yes | - | Low | - |
| *Hypericum densiflorum* common St. John's wort | FAC | Mesic | 2-4 | H | M | M | H | Sun | Ovoid shrub | 3-6' | Shallow | Yes | - | Med. | - |
| *Ilex glabra* inkberry | FACW | Mesic to wet Mesic | 2-4 | H | H | - | H | Sun to partial sun | Upright dense shrub | 6-12' | Shallow | Yes | - | High | Coastal plain species |
| *Ilex verticillata* winterberry | FACW | Mesic to wet Mesic | 2-4 | L | M | - | H | Sun to partial sun | Spreading shrub | 6-12' | Shallow | Yes | - | High | - |
| *Juniperus communis "compressa"* common juniper | FAC | Dry Mesic - Mesic | 1-2 | M | H | H | M - H | Sun | Mounded shrub | 3-6' | Deep taproot | - | Yes | High | Evergreen |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

## TABLE 3.11-7B RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- SHRUB SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name* Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Juniperus horizontalis "Bar Harbor"* creeping juniper | FAC | Dry Mesic - Mesic | 1-2 | M | H | H | M - H | Sun | Matted shrub | 0-3' | Deep taproot | - | Yes | High | Evergreen |
| *Lindera benzoin* spicebush | FACW | Mesic to wet Mesic | 2-4 | H | - | - | H | Sun | Upright shrub | 6-12' | Deep | Yes | - | High | - |
| *Myrica pennsylvanica* bayberry | FAC | Mesic | 2-4 | H | M | M | H | Sun to partial sun | Rounded, compacted shrub | 6-8' | Shallow | Yes | - | High | Coastal plain species |
| *Physocarpus opulifolius* ninebark | FAC | Dry Mesic to wet Mesic | 2-4 | M | - | - | H | Sun | Upright shrub | 6-12' | Shallow | Yes | - | Med. | May be difficult to locate. |
| *Viburnum cassinoides* northern wild raisin | FACW | Mesic | 2-4 | H | H | H | H | Sun to partial sun | Rounded, compacted shrub | 6-8' | Shallow | Yes | - | High | - |
| *Viburnum dentatum* arrow-wood | FAC | Mesic | 2-4 | H | H | H | H | Sun to partial sun | Upright, multi-stemmed shrub | 8-10' | Shallow | Yes | - | High | - |
| *Viburnum lentago* nannyberry | FAC | Mesic | 2-4 | H | H | H | H | Sun to partial sun | Upright, multi-stemmed shrub | 8-10' | Shallow | Yes | - | High | - |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

## TABLE 3.11-7C RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- HERBACEOUS SPECIES

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name*<br>Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects Disease | Exposure | Form | Height | Root System | Native | Non-native | Wildlife | |
| *Agrostis alba*<br>redtop | FAC | Mesic - Xeric | 1-2 | H | - | H | H | Shade | Grass | 2-3' | Fiberous Shallow | Yes | - | High | - |
| *Andropogon gerardi*<br>bluejoint | FAC | Dry Mesic - Mesic | 1-2 | - | - | - | - | Sun | Grass | 2-3' | Fiberous Shallow | Yes | - | High | - |
| *Deschampsia caespitosa*<br>tufted hairgrass | FACW | Mesic to wet Mesic | 2-4 | H | - | H | H | Sun | Grass | 2-3' | Fiberous Shallow | Yes | - | High | May become invasive. |
| *Hedera helix*<br>English ivy | FACU | Mesic | 1-2 | - | - | - | H | Sun | Evergreen ground cover | - | Fiberous Shallow | - | Yes | Low | - |
| *Lotus Corniculatus*<br>birdsfoot-trefoil | FAC | Mesic - Xeric | 1-2 | H | L | H | H | Sun | Grass | 2-3' | Fiberous Shallow | Yes | - | High | Member of the legume family. |
| *Pachysandra terminalis*<br>Japanese pachysandra | FACU | Mesic | 1-2 | - | - | - | M | Shade | Evergreen ground cover | - | Fiberous Shallow | - | Yes | Low | - |
| *Panicum virgatum*<br>switch grass | FAC to FACU | Mesic | 2-4 | H | - | - | H | Sun or Shade | Grass | 4-5' | Fiberous Shallow | Yes | - | High | Can spread fast and reach height of 6'. |
| *Parthenocissus Tricuspida*<br>Boston ivy | FACU | Mesic | 1-2 | - | - | - | H | Shade | Evergreen ground cover | | Fiberous Shallow | - | Yes | Low | May need to be trimmed back often. |
| *Vinca major*<br>large periwinkle | FACU | Mesic | 1-2 | - | - | - | H | Shade | Evergreen ground cover | - | Fiberous Shallow | - | Yes | Low | Sensitive to soil compaction and pH changes. |
| | | | | | | | | | | | | | | | |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

## MINIMUM STANDARD 3.11A

# BIORETENTION FILTERS

### Definition

Bioretention basins that rely on infiltration (**MINIMUM STANDARD 3.11: BIORETENTION BASINS**) may not be feasible in many ultra-urban settings because of the proximity of building foundations or because soils are not conducive to exfiltration from the basin. **Bioretention Filters** were developed for use in such circumstances.

Bioretention soil media filters are essentially bioretention basins with the infiltration chamber gallery equipped with a permanent and continuous connection to the storm sewer system. The bioretention basin shown in **Figure 3.11A-1** illustrates a bioretention basin equipped to function as a filter.

When used in areas underlain by marine clays or in proximity to building foundations, the entire basin must be provided with a dense clay or geomembrane liner. When the filter concept must be used simply because of low percolation rates of the soil, the liner may be omitted. The vertical sand column is also optional on a bioretention filter.

### Purpose

Water Quality Enhancement

Like bioretention basins, bioretention filters are used primarily for water quality control. Bioretention filters enhance the quality of stormwater runoff through the processes of adsorption, filtration, volitization, ion exchange, microbial and decomposition prior to collection of the treated effluent in the collector pipe system. Microbial soil processes, evapotranspiration, and nutrient uptake in plants also come into play (Bitter and Bowers, 1995). The manner in which these processes work is discussed under **MINIMUM STANDARD 3.11, BIORETENTION BASINS**. The minimum widths and lengths for bioretention basins (10' and 15', respectively) also apply to bioretention filters. However, since runoff will be treated faster in a bioretention filter, it may be pooled to a maximum depth of 1 foot above the basin floor rather than the 0.5 feet allowed in a bioretention basin. **Table 3.11A-1** contains the target removal efficiencies for bioretention filters in which a **mature** forest community has been created, based on the volume of runoff to be filtered.

**FIGURE 3.11A-1**
*Bioretention Filter*

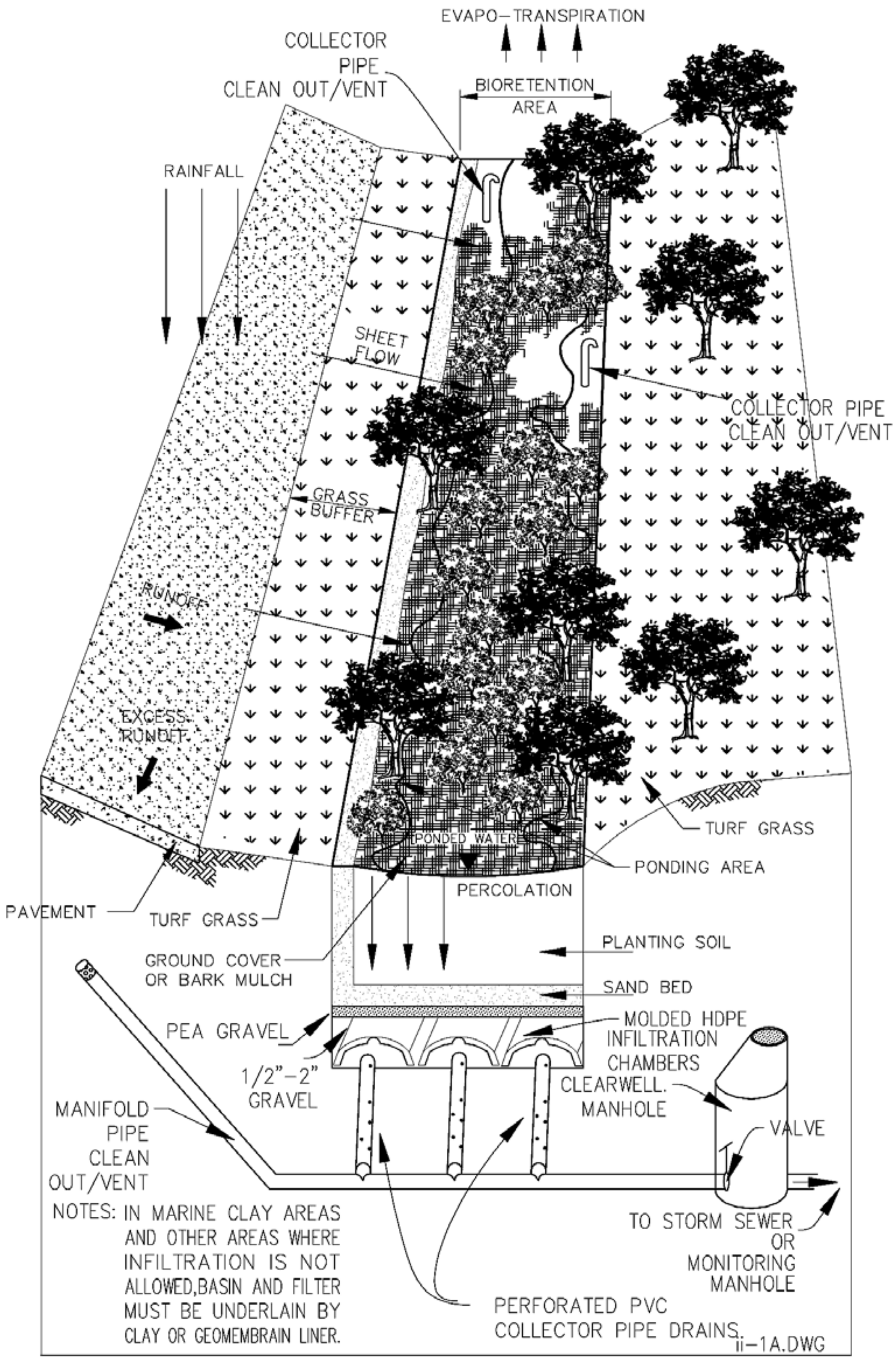


**TABLE 3.11A - 1**
***Pollutant Removal Efficiencies for Bioretention Filters***

| BMP Description | Target Pollutant Removal Efficiency (Phosphorous) |
|---|---|
| Bioretention filter with capture and treatment volume equal to 0.5 inches of runoff from the impervious area. | 50% |
| Bioretention filter with capture and treatment volume equal to 1.0 inches of runoff from the impervious area. | 65% |

Flood Control and Channel Erosion Control

The amount of flood and channel erosion control protection provided by bioretention basins depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

## Conditions Where Practice Applies

Bioretention Filters are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal efficiency. The critical prerequisite is the existence of a deep enough storm sewer to accept drainage from the collector pipe system by gravity flow. All of the applications shown in **Figures 3.11-2** through **3.11-6** under **MS 3.11** may be built as bioretention filters. As with bioretention basins, for large applications, several connected bioretention filters (another type of "Green Alleys") are preferable to a single, massive filter. Such systems are especially desirable along the landward boundary of reduced Chesapeake Bay Resource Protection Areas. **MS 3.11B** discusses this system. Considering the character of bioretention basins, some jurisdictions may qualify them as buffer restoration.

## Planning Considerations

Site Conditions

Except for those dealing with proper soils to accept infiltration and sizing of the filters, all of the **Site Conditions** considerations for bioretention basins contained in **MINIMUM STANDARD 3.11: BIORETENTION BASINS** also apply to bioretention filters. The same drainage area range applies, as do the same **Location Considerations.** In addition to site conditions, the following apply specifically to bioretention filters.

**1. Sizing Guidelines**

For planning purposes, assume that the floor area of a bioretention filter will be 2.5% of the impervious area draining to the filter if 0.5 inches of runoff are to be treated and 5.0% of the impervious area on the drainage shed if the first 1.0 inches of runoff are to be treated.

**2. Aesthetic Considerations**

All of the discussion of aesthetics under **MINIMUM STANDARD 3.11: BIORETENTION BASINS** apply equally to bioretention filters. Overall aesthetics of the bioretention filters must be integrated into the site plan and stormwater concept plan from their inception. Biomorphic shapes which follow the ground contours should be used rather than angular shapes. The bioretention filter should be essentially almost invisible upon completion, blending in with the other landscaping of the site. Both the stormwater engineer and the landscaping planner must participate in the layout of the facilities and infrastructure to be placed on the site.

Sediment Control

All of the **Sediment Control** considerations for bioretention basins under **MS 3.11: Bioretention Basins** also apply to bioretention filters.

***Like bioretention basins, bioretention filters should be constructed only AFTER the site work is complete and stabilization measures have been implemented. Experience with bioretention basins and soil media filters has demonstrated that bioretention filters must be protected from all sediment loads.***

Bioretention filters must retain sediment control protection until stabilization of the upland site is functional to control the sediment load from denuded areas. Provisions to bypass the stormwater away from the bioretention filter during the stabilization period must be implemented.

## General Design Criteria

The purpose of this section is to provide minimum criteria for the design of bioretention filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements. Bioretention filters which capture and treat the first one inch of runoff from impervious surfaces may also provide streambank erosion protection.

General

The design of bioretention filters should be in accordance with the following Minimum Standards where applicable: **3.1: Earthen Embankments, 3.2: Principal Spillways, 3.3: Vegetated Emergency Spillways, 3.4: Sediment Forebay,** as well as the additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for the particular design but also for ensuring long-term operation.

Integration of the bioretention filters into the general landscaping scheme of the project must be coordinated with the landscaping professional at the inception of the design process. Use of such techniques as biomorphic shapes to present a pleasing aesthetic appearance is of equal importance with hydrological and hydraulic functioning of the basins. Properly designed bioretention filters should not be readily identifiable as stormwater BMPs by the lay observer.

Basin Sizing Methodology

In Virginia, bioretention filters are designed to filter the treatment quantity into the underlying gravel bed and collector pipe system. **Bioretention filters are sized using the same sizing methodology as that of bioretention basins**.

The elevation of the overflow structure should be 1.0 feet above the elevation of the bioretention bed.

The **Runoff Pretreatment, Drainage Considerations**, and **Exclusion of Continuous Flows and Chlorinated Flows** considerations of **MINIMUM STANDARD 3.11: BIORETENTION BASINS**, are also applicable to bioretention filters. If the filter soil remains constantly wet, anaerobic conditions will develop, which will kill the plants and cause iron phosphates which have been previously captured to break down and escape into the effluent.

***Continuous or frequent flows (such as basement sump pump discharges, cooling water, condensate water, artesian wells, etc.) and flows containing swimming pool and sauna chemicals must be EXCLUDED from routing through bioretention or bioretention filter BMPs since such flows will cause the BMP to MALFUNCTION!***

The **Planting Plan, Planting Soil Guidelines, Mulch Layer Guidelines, Plant Material Guidelines, Plant Growth and Soil Fertility** criteria of **MINIMUM STANDARD 3.11: BIORETENTION BASINS**, also apply to bioretention filters.

Basin Liners

Impermeable liners may be either clay, concrete or geomembrane. If geomembrane is used, suitable geotextile fabric shall be placed below and on the top of the membrane for puncture protection. Clay liners shall meet the specifications in **Table 3.11A-2**.

The clay liner shall have a minimum thickness of 12 inches.

If a geomembrane liner is used it shall have a minimum thickness of 30 mils and be ultraviolet resistant.

The geotextile fabric (for protection of geomembrane) shall meet the specifications in **Table 3.11A-3**.

**TABLE 3.11A - 2**
***Clay Liner Specifications*** (Source: City of Austin)

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| Permeability | ASTM D-2434 | Cm/Sec | $1 \times 10^{-6}$ |
| Plasticity Index of Clay | ASTM D-423 & D-424 | % | Not less than 15 |
| Liquid Limits of Clay | ASTM D-2216 | % | Not less than 30 |
| Clay Compaction | ASTM-2216 | % | 95% of Standard Proctor Density |
| Clay Particles Passing | ASTM D-422 | % | Not less than 30 |

**TABLE 3.11A - 3**
***Geotextile Specification for Basin Liner "Sandwich"***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| Unit Weight | | Oz./Sq.Yd. | 8 (minimum) |
| Filtration Rate | | In./Sec. | 0.08 (minimum) |
| Puncture Strength | ASTM D-751 (Modified) | Lb. | 125 (minimum) |
| Mullen Burst Strength | ASTM D-751 | Psi. | 400 (minimum) |
| Tensile Strength | ASTM D-1682 | Lb. | 300 |
| Equiv. Opening Size | U.S. Standard Sieve | No. | 80 (minimum) |

Source: City of Austin

Equivalent methods for protection of the geomembrane liner will be considered on a case by case basis. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing and abrasion.

When molded chambers are incorporated into the design, a minimum of four inches of gravel or crushed stone should be added beneath the molded chambers or other conveyance system to allow settling of filter fines into the voids. As with bioretention basins, filter strips, grassed channels, and side slopes should be sodded with mature sod, and planting soil should be wrapped up the side slopes under the sod.

All other factors dealing with bioretention filters are identical to those for bioretention basins in general, **M.S.3.11.**

## MINIMUM STANDARD 3.11B

# GREEN ALLEYS

### Definition

Green Alleys consist of a network of bioretention basins/infiltration trenches or bioretention filters that provide both redundant water quality management and stormwater conveyance to stormwater management facilities. They create a carefully landscaped green border along, or a dividing corridor through, a development site. Unless otherwise noted, the information on Green Alleys in this section was provided by Keith Bowers of Biohabitats, Inc.

Green Alleys combine the redundancy of multiple stormwater quality BMPs and stormwater conveyance with urban and suburban site design features. Using bioretention, infiltration, and filtration as a foundation, Green Alleys consist of an above ground and below ground green ribbon of interconnecting BMPs that treat the first flush of stormwater while conveying excess runoff to management facilities. While Green Alleys provide an ecosystem based stormwater management technique, they also connect and facilitate the awareness of natural ecologic and hydrologic cycles.

Above ground, Green Alleys consist of a strip (greenway) consisting of native trees, schrubs, and groundcover that replicates native forest ecosystems and landscape processes to enhance sormwater quality. Green Alleys can also consist of a mixture of hardscape and landscape incorporating such features as walkways, urban plazas, open spaces, and streetscapes. Below ground, Green Alleys consist of sand filters and infiltration trenches that are connected by a series of perforated and solid pipes or molded plastic infiltration galleries that convey excess stormwater to quantity management facilities.

### Purpose

Like bioretention basins and bioretention filters, green alleys are used primarily for water quality control. A number of other benefits may also accrue from green alleys. They provide redundancy in the number of treatment techniques and, except where precluded by soil conditions, some opportunity for infiltration even where filters are used; they may reinforce the visual and physical connection between the urban environment and the surrounding natural features; they may provide a greenway corridor (hedgerow) for wildlife habitat and/or pedestrian circulation; they may provide a green buffer between different land uses; and the system continues to function even if individual parts fail.

Water Quality Enhancement

As with other bioretention facilities, the treatment volume is managed and treated through microbial action and soil chemestry (nutrient cycling), evaportransporation, adsorption, and, where applicable, soîl infiltration. The manner in which these processes work is discussed under **MINIMUM STANDARD 3.11, BIOTETENTION BASINS**. **Table 3.11B-1** provides pollutant removal efficiencies for Green Alleys based on the volume of water to be treated.

**TABLE 3.11B - 1**
***Pollutant Removal Efficiencies for Green Alleys***

| BMP Description | Target Pollutant Removal Efficiency (Phosphorous) |
|---|---|
| Green Alleys with capture and treatment volume equal to 0.5 inches of runoff from the impervious area. | 50% |
| Green Alleys with capture and treatment volume equal to 1.0 inches of runoff from the impervious area. | 65% |

Flood Control and Channel Erosion Control

The amount of flood and channel erosion control provided by Green Alleys depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined. As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

## Conditions Where Practice Applies

Green Alleys are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal eccifiency. The critical prerequisite is the existence of a deep enough storm sewer to accept drainage from the collector pipe system by gravity flow. All of the applications shown in **Figures 3.11-2** through **3.11-6** under **MS 3.11** may be built as bioretention filters.

## Planning Considerations

### Stormwater Management Concept Plan

Like all bioretention facilities, Green Alleys must be planned within the context of an overall stormwater management concept plan which addresses potential flooding and streambank erosion protection as well as water quality. This concept plan must be developed very early in the planning process to assure that sufficient space in the proper hydrological and hydraulic locations is reserved for stormwater management facilities. Minimum information necessary to develop a stormwater concept plan includes: existing and proposed drainage areas, size and capacity of downstream drainage conveyances, soils stidies, existing vegetation, and hydrographic features such as streams, floodplains, and wetlands, boundaries of Chesapeake Bay Preservation Resource Protection Areas. The plan must address the proposed location of areas of impervious cover on the site, the methods for collection and conveyance of runoff to an adequate channel or conduit, proposed detention facilities to address streambank erosion and potential flooding, and the proposed methods of providing quality treatment of the runoff.

### Site Conditions

The **Site Conditions** considerations for for bioretention basins contained in **MINIMUM STANDARD 3.11: BIORETENTION BASINS** and **MS 3.11A: Bioretention Filters**, apply to Green Alleys which employ these BMPs. The same drainage area range applies, as do the same **Location Considerations.** In addition to site conditions, the following apply specifically to bioretention basins.

All other considerations for **M.S. 3.11, Bioretention Basins**, apply to Green Allies.

Chapter 3.11

Bioretention Filter in ultra-surban setting. Note curb cut, gravel energy dissipater, and clean out/observation wells.

Bioretention Filter located in required parking lot green space.

# Bioretention Basin Practices

Bioretention Filter in multi-family residential setting.

Bioretention Basins in office setting parking lot.

# Bioretention Basin Practices

# *MINIMUM STANDARD 3.12*

# GENERAL INTERMITTENT SAND FILTERS



View BMP Images

# LIST OF ILLUSTRATIONS

# LIST OF ILLUSTRATIONS cont.

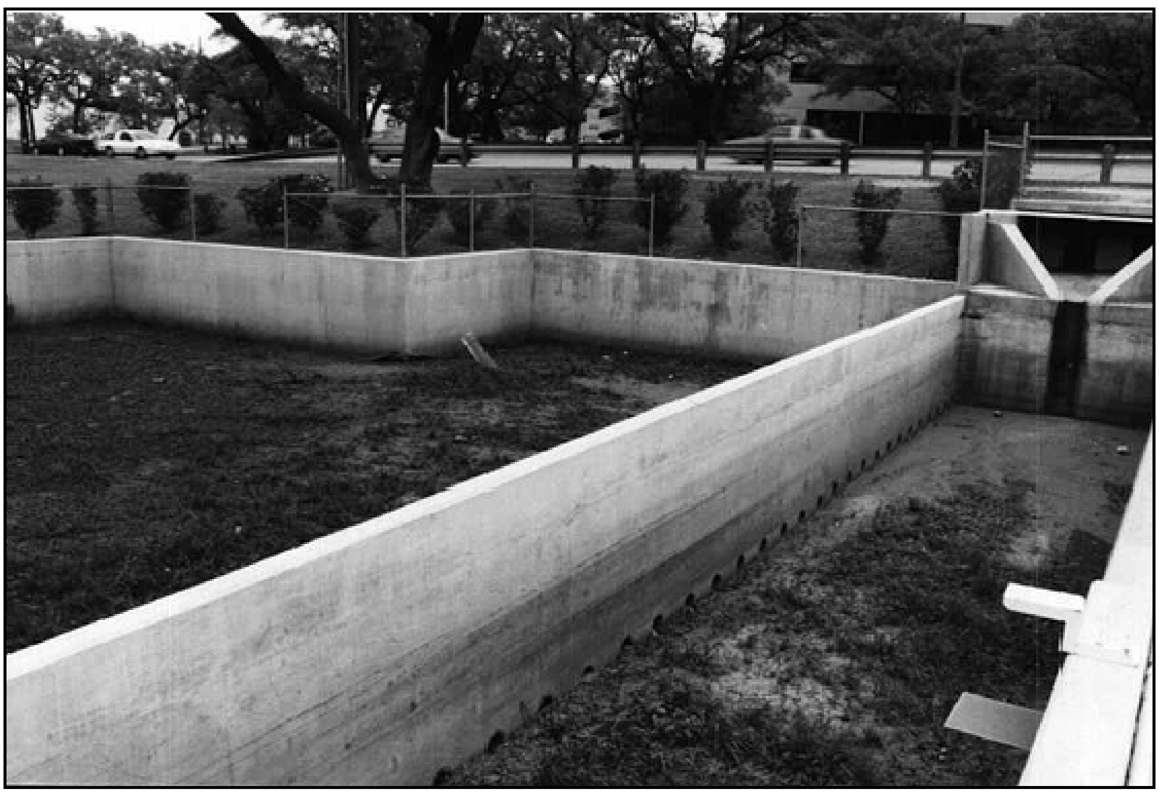
## MINIMUM STANDARD 3.12

# GENERAL INTERMITTENT SAND FILTER PRACTICES

### Definition

Intermittent sand filter facilities capture, pretreat to remove sediments, store while awaiting treatment, and treat to remove pollutants (by percolation through sand media) the most polluted stormwater (the water quality volume) from a site. Intermittent sand filter BMPs may be constructed in underground vaults, in paved trenches within or at the perimeter of impervious surfaces, or in either earthen or concrete open basins. They have been successfully used in Austin Texas, the District of Columbia, The State of Delaware, and in Alexandria, Virginia over the last two decades. **Figure 3.12-1** is a photograph of a sand filter BMP in Austin.

**FIGURE 3.12 - 1**
***Austin Partial Sedimentation Surface Sand Filter***



(Photo Courtesy of City of Austin, Texas)

## Purpose

Intermittent sand filter facilities are primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity facilities must be provided. Table 3.12-1 contains the target removal efficiencies of sand and other soil media filter BMPs. Table 3.12-2 contains the results of an extensive sand filter monitoring study in Alexandria conducted for the Chesapeake Bay Local Assistance Department (Bell, Stokes, Gavan, and Nguyen, 1995).

**TABLE 3.12-1**
Pollutant Removal Efficiency for Intermittent Sand Filter Facilities

| BMP Description | Target Phosphorus Removal Efficiency |
|---|---|
| Intermittent Sand Filter treating 0.5 inches of runoff from the impervious area. | 65% |

## Pollutant Removal Mechanisms at Work in Intermittent Sand Filter BMPs

Pollutant removal processes at work in intermittent sand filters are complex and involve physical, chemical, and biological transformations (Tchobanoglous and Burton, 1991; Anderson, Siegrist, and Otis, Undated). The most obvious mechanism is physical straining of suspended solids and particulate nutrients.

**Suspended Solids**

Mechanical straining, straining due to chance contact, and sedimentation are the principal mechanisms by which suspended solids are removed, although the growth of bacterial colonies within the sand grains may also cause autofiltration (Tchobanoglous and Burton, 1991).

**Table 3.12-2**
***Pollutant Removal Efficiencies for a Delaware Sand Filter in Alexandria***

| Constituent | Mass Balance Removal Efficiency (%) |
|---|---|
| Cadmium | NA |
| Copper | NA |
| Zinc | >90.7 |
| Iron | NA |
| Ammonia Nitrogen | >39.0 |
| Nitrite Nitrogen | >45.8 |
| Nitrate Nitrogen | -62.7 |
| $NO_x$ | -53.3 |
| Total Kjeldahl Nitrogen | 70.6 |
| Total Phosphorous | 63.1/72.3[1] |
| Ortho-Phosphorous | >68.3/74.4[1] |
| Total Suspended Solids | >78.8/>83.9[2] |
| Hardness | 38.5 |
| Biochemical Oxygen Demand (5 Day) | >77.5 |
| Total Petroleum Hydrocarbons | >84[3] |
| Total Organic Carbon | 65.9 |

[1] Excluding Anaerobic Incident Data [2] Excluding Storms with Heavy Iron Export
[3] Average Removal from Alaska Marine Lines Filter 3 in Seattle, Washington (Horner,1995)

**Phosphorous**

Phosphorous removal is performed by physiochemical processes such as mechanical and chance contact straining, precipitation, and adsorption (Piluk and Hao, 1989; Laak, 1986).

There are three general types of adsorption (the condensation and concentration of ions or molecules of one material [the adsorbate] on the surface of another [the adsorbent]): physical, chemical, and exchange. Physical adsorption results from the weak forces of attraction between molecules and is generally quite reversible. Chemical adsorption results from much stronger forces comparable to those leading to the formation of chemical compounds, with the adsorbed material forming a one molecule thick layer over the surface of the absorbent until the capacity of the absorbent is exhausted. Chemical adsorption is seldom reversible. Exchange adsorption, on the other hand, results from electrical attraction between the adsorbate and the surface, such as occurs with ion exchange. Ions of the adsorbate concentrate on the surface of the adsorbent as a result of electrical attraction to opposite charges on the surface. It is sometimes difficult to assign a given adsorption to a specific type (Sawyer, Mcarty, and Parkin, 1994).

Although exchange adsorption may also be involved, most adsorption in intermittent sand filters appears to be chemical adsorption (Piluk and Hao, 1989; Otis, Undated; Anderson, Siegrist, and Otis, Undated).

In addition to the **filter mass available**, the adsorption of phosphorous in sand filters is also affected by the pH of the material being filtered (with higher removal rates occurring with the reduction of pH), temperature, contact time, and the character of the filter media (Laak, 1986). Sands containing iron, aluminum, or calcium have a higher phosphorous removal potential because phosphorous will combine with these elements through chemical precipitation and become relatively insoluble (Laak, 1986, Tchobanoglous and Burton, 1991). If the filter becomes anaerobic, the bonding with iron may break down, releasing orthophosphates (Harper and Herr, 1993). However, aerobic filters enriched with iron may attain almost complete phosphorous removal until the filter capacity is exhausted, and properly sized filters may have a life of up to 20 years (Laak, 1986). Sand particles with sufficient iron content may become positively charged, leading to more favorable medium-particle interactions and increased removal rates (Stenkamp and Benjamin, 1994). Entrapment in the filter of a high percentage of the iron in the runoff being treated may provide a source to replenish used up phosphorous adsorption capacity.

<u>**Nitrogen and Biochemical Oxygen Demand**</u>

Mineralization of organic nitrogen into ammonium ($NH^{+}_{4}$) may occur under either aerobic or anaerobic conditions if the required naturally occurring chemoautotrophic bacteria (organisms which obtain energy by oxidizing simple chemical compounds) are present (*Nitrosomonas, Nitrosococcus, Nitrospira, Nitrosolobus, Nitrososovibrio*) ((Laak, 1986; The Cadmus Group, 1991).

Organic N 6 Bacterial enzymes 6 $NH_4^+$ + other products

Positively charged ammonium ions are then adsorbed to negatively charged sand filter particles through exchange adsorption (The Cadmus Group, 1991).

The transformation of ammonia ($NH_3$) and ammonium into nitrite and nitrate ($NO_2^-$ and $NO_3^-$) and the removal of $BOD_5$ occur under aerobic conditions by microorganisms (such as *Nitrosomonas* and *Nitrobacter*) present in the sand bed (Tchobanoglous and Burton, 1991;, Laak, 1991; The Cadmus Group, 1991).

$NH_4^+ + 1.5O_2$ 6 *Nitrosomonas*, etc 6 $NO_2^- + 2H + H_2O$ + Energy

$NO_2^- + 0.5O_2$ 6 *Nitrobacter* 6 $NO_3^-$ + Energy

Since nitrite and nitrate are soluble anions, they are not affected by the cation exchange complex of the filter, but rather tend to leach readily to the filter effluent (Gold, Lamb, Loomis, and McKiel, Undated). However, anaerobic microenvironments (sometimes called "microsites") routinely coexist in principally aerobic intermittent sand filters (Tchobanoglous and Burton,1991; Gold, Lamb, Loomis, and McKiel, Undated). Naturally occurring anaerobic bacteria (*Pseudomonas, Micrococcus*, *Achromobacter, Bacilluss*) in these pockets may convert much of the nitrite into nitrate and the nitrate to nitrogen gas, resulting in total nitrogen removal in intermittent sand filters ranging up to 45-50 percent (Tchobanoglous and Burton, 1991; Laak, 1986; Ronayne, Paeth, and Osborne, Undated).

$NO_3^-$ + Organic Carbon 6 Denitrifying bacteria 6 $N_2 + H_2O + CO_2$ + Cells

Organic carbon must be present for denitrification to occur, but low organic carbon/nitrogen rations will suffice (1:2 or less) (Laak, 1986, p.62). Some studies indicate that optimal denitrification occurs at ratios of 1:1-3:1 (Gold, et al, p.298). The maximum rate of denitrification occurs at temperatures above 10 degrees C and at a pH above 5.5, with the optimum pH range falling between 7.0 and 8.0. (The Cadmus Group, 1991, p.11). However, home wastewater systems have demonstrated excellent denitrification performance when the wastewater temperature was as low as 4 degrees C (Piluk and Hoa, 1989).

## Heavy Metals

More than 70 percent of heavy metals in stormwater runoff is in particulate form (Harper and Herr, 1993). Over 70 percent of particulate heavy metals are of greater than 104 microns in size (Shaver and Baldwin, 1990). Particle settling in presettling basins and mechanical straining appear to be the principal mechanism for removing heavy metals in stormwater intermittent sand filter systems. Some iron may be removed by reacting with phosphorous in the runoff being treated.

## Hydrocarbons

Mechanical straining and physical adsorption appear to be the mechanisms removing hydrocarbons which reach the sand filter.

## Conditions Where Practice Applies

Intermittent sand filters are suitable for use in ultra-urban settings with a high degree of imperviousness where the land cost or loss of economic return on real estate required to construct retention basins may be prohibitive. They are generally suited for high pollutant removal on medium to high density development (65 to 100% impervious cover). Specific conditions such as drainage area size and development conditions are discussed with each type of intermittent sand filter. Because they are subject to failure by clogging, intermittent sand filters are not recommended for use on watersheds where sediment loadings can be significant. Wherever possible, their use should be limited to treating runoff from impervious surfaces. Most of the practices discussed below are designed to treat runoff from watersheds with at least 65% impervious cover. Where other runoff must be treated, sediment protection must be increased to severely curtail the sediment load reaching the filter media.

## Planning Considerations

### Site Conditions

**1.** ***Size and Topography of the Site***

Some types of intermittent sand filter BMPs are especially suited to larger drainage sheds, while others have upper size limits on their effective use. **Table 3.12-3** outlines drainage shed size applications of various types of intermittent sand filter facilities. On larger sites with multiple drainage sheds, a variety of BMPs might prove to be most cost effective.

**TABLE 3.12 - 3**
***Appropriate Intermittent Sand Filter Applications to Various Site Areas***

| Type of Intermittent Sand Filter | Appropriate Drainage Shed to filter |
|---|---|
| District of Columbia Underground Vault Sand Filters | Medium (0.25-1.25 impervious acres) |
| Delaware Sand Filters | Small-Medium ($\leq$ 1.25 impervious acres) |
| Austin Full Sedimentation Sand Filters (Surface or Vault) | Large ($\geq$ 1.25 impervious acres) |
| Austin Partial Sedimentation Sand Filters (Surface) | Medium-Large |
| Austin Partial Sedimentation Sand Filters (Underground) | Medium |

**2. *Stormwater Infrastructure Serving Site***

Both the size and the elevations of stormwater infrastructure serving the site as a whole are important considerations. A critically important design parameter is the potential difference in elevation of the receiving manhole in the stormwater infrastructure and the elevation of the closest manhole in the new storm sewer system draining the site to be served. This will determine the depth of water than can be pooled above the filter media with the system operating on gravity flow. Almost all intermittent sand filter BMPs are designed to flow by gravity. However, in commercial and industrial applications where dedicated maintenance crews with familiarity with mechanical equipment will be available, pumped flow should be considered a viable alternative.

**3. *Depth to Seasonally High Groundwater Table***

The liner or concrete shell of intermittent sand filter BMPs is usually placed at least 2 to 4 feet above the seasonally high water table or bedrock in order to assure dry conditions for construction and to minimize infiltration of groundwater into the filter structure. However, in some cases, it may be economical and practical to place filter shells below the seasonally high water table. In such cases, floatation effects must be countered by providing extra weight or hold down components in the filter shell.

**4. *Value of the Real Estate and Expected Income from Development***

The value of real estate in highly urbanized areas may drive the overall cost of traditional structural BMPs too high for serious consideration. In Alexandria, for example, the cost of real estate alone to construct retention ponds averages $60,000 per impervious acre treated, while the cost of real estate for extended detention basins averages $40,000 per impervious acre treated. The overall costs of underground vault sand filters, which may be placed under parking lots and private streets or even within building structures and therefore have no real estate cost, can become quite competitive under such circumstances. The income stream from increased development allowed by underground BMPs should also be considered in such analyses.

**5. *Aesthetic and Land Use Considerations***

Most traditional stormwater BMPs may be severely lacking in visual attractiveness. This may be especially true with some extended detention basins and retention basins lacking a base flow to prevent eutrophication during hot, dry weather. Questions also often arise about the use of valuable open space on projects for BMPs instead of alternative uses such as recreation. Most sand filter BMPs are visually unobtrusive and may be used in situations where aesthetic considerations or open space use are important.

## Sediment Control

Intermittent sand filter BMPs which have been subjected to heavy sediment loadings have historically failed very quickly (LaRock, 1988; Harper and Herr, 1993). In a study in Denver, Colorado, Urbonis, Doerfer, and Tucket found that the hydraulic conductivity of a sand filter serving an equipment parking lot dropped rapidly as sediment accumulated on the surface of the filter (Urbonis, Doerfer, and Tucker, 1996). A layer of sediment approximately 1/16 inch (1.6 millimeters) thick was found to limit hydraulic conductivity to 0.05 feet per hour (1.6 ft/day), considerably less than the design coefficient of permeability used by Northern Virginia jurisdictions in the design of sand filters (*ibid.;* Bell, Stokes, Gavan, and Nguyen, 1995). The filter media of intermittent sand filter BMPs must therefore be protected from excessive sediment loads. This requires isolation during construction of the development, site design to restrict the amount of runoff from pervious areas reaching the filter after construction, and proper sizing of sediment removing features of the BMP to match final site conditions.

**1.** ***Construction Runoff***

> *Sand filter BMPS must* ***never*** *be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

When this precaution has not been taken in the past, the sand filter BMPs have become clogged with sediment from upland construction operations almost immediately, requiring complete reconstruction of the sand filter and sometimes the collector pipe system. This can prove very expensive. However, since most sand filter BMPs are constructed off-line with a flow splitting device employed to divert only the Water Quality Volume to the filter, the BMP may usually be completely constructed but isolated from runoff by blocking the inflow pipe until the site is fully stabilized.

**2.** ***Urban Runoff***

While experience indicates that intermittent sand filters fail very quickly when directly exposed to runoff from watersheds with low imperviousness and poor vegetated cover (LaRock, 1988; Harper and Herr, 1993), filters which treat runoff from almost exclusively impervious areas, such as highway surfaces, may perform satisfactorily for several years with very little maintenance (Shaver and Baldwin, 1991).

An 18-month, comprehensive study of runoff from street surfaces in 12 cities throughout the U.S. determined that, while most particulate matter is in the fractions equating to sand and gravel, the approximately 6 percent of particles in the silt and clay soil size contain over half the phosphorous and some 25 percent of other pollutants (Sartor, Boyd, and Agardy, 1974). **Table 3.12-4** illustrates this finding.

In planning the layout for a site on which sand filter BMPs are to be employed, care should be taken to direct only runoff from impervious surfaces to the filter insofar as possible. The drainage sheds feeding sand filter BMPs with only partial sediment protection (as delineated in the individual BMP discussions which follow) should ***never*** contain less than 65% impervious cover. Even when full sediment protection is provided in the form of a carefully sized presettlement basin, the amount of runoff from pervious areas directed to the filter must be minimized. The Denver study also indicates that full sediment protection may be required in areas subject to heavy atmospheric deposition of suspended solids even when only runoff from impervious surfaces is being treated.

The presettling basin or sedimentation chamber of an intermittent sand filter BMP is expected to remove all but the very fine particles of sediment, while most of the other pollutant removal is expected to occur in the sand filter, where the very fine particles will be trapped.

**TABLE 3.12-4**
***Percent of Street Pollutants in Various Particle Size Ranges***

| | Particle Size (Microns) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant** | **>2000** | **840-2000** | **246-840** | **104-246** | **43-104** | **<43** |
| Total Solids | 24.4 | 7.6 | 24.6 | 27.8 | 9.7 | 5.9 |
| Volatile Solids | 11.0 | 17.4 | 12.0 | 16.1 | 17.9 | 25.6 |
| COD | 2.4 | 4.5 | 13.0 | 12.4 | 45.0 | 22.7 |
| $BOD_5$ | 7.4 | 20.1 | 15.7 | 15.2 | 17.3 | 24.3 |
| TKN | 9.9 | 11.6 | 20.0 | 20.2 | 19.6 | 18.7 |
| Phosphates | 0 | 0.9 | 6.9 | 6.4 | 29.6 | 56.2 |
| All Toxic Metals | 16.3 | 17.5 | 14.9 | 23.5 | - | 27.8 |

(Source: Shaver and Baldwin, 1990; adapted from Sartor, Boyd, and Agardy, 1974)

**<u>Trash Exclusion</u>**

Underground vault BMPs are confined space under Occupational Safety and Health Regulations and are therefore more expensive to enter and maintain than open facilities. Future operations and maintenance costs can substantially reduced by assuring that trash is, insofar as possible, excluded from entering the vault. Grated storm inlets and trash racks in flow splitters are two ready solutions to this problem.

**<u>Projected Hydrocarbon Loadings</u>**

Sand filters will quickly clog when subjected to direct heavy hydrocarbon loadings. Where such loadings are expected, a design which removes unemulsified hydrocarbons in a separate chamber or structure in the treatment train ahead of the filter should be selected.

## Maintenance

The maintenance requirements for intermittent sand filters must be considered during the planning and design of the facility. All chambers of underground sand filters must have personnel access manholes and built-in access ladders . Access roads or streets must be of sufficient width and bearing capacity to support dump trucks loaded with accumulated sediments or heavy vacuum (e.g.”VACTOR”) trucks for removing accumulated sediments and hydrocarbons from sediment chambers and traps on a regular basis. Approximately every 3-5 years, the filter can be expected to clog to the point that replacement of the top few inches of sand or, where employed, the layer of washed gravel and the top layer of filter cloth will be required. **A minimum maintenance headspace of 60 inches above the filter is required in underground vault filters BMPs.** A 36-38-inch diameter maintenance manhole with a small, concentric personnel access lid or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter. Large sedimentation basins and open filters must be equipped with access ramps to allow small earthmoving equipment such as “Bobcats” and light trash raking equipment to go into the basins. Finally, before finalizing the BMP design, follow the advice of Joseph J. Skupien, Principal Hydraulic Engineer of Somerset County, New Jersey, and “close your eyes, kick back, and think your BMP through a full year of operations, visualizing how it will perform under the conditions of all four seasons.”

## General Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of intermittent sand filter practices intended to comply with the Virginia Stormwater Management program’s runoff quality requirements.

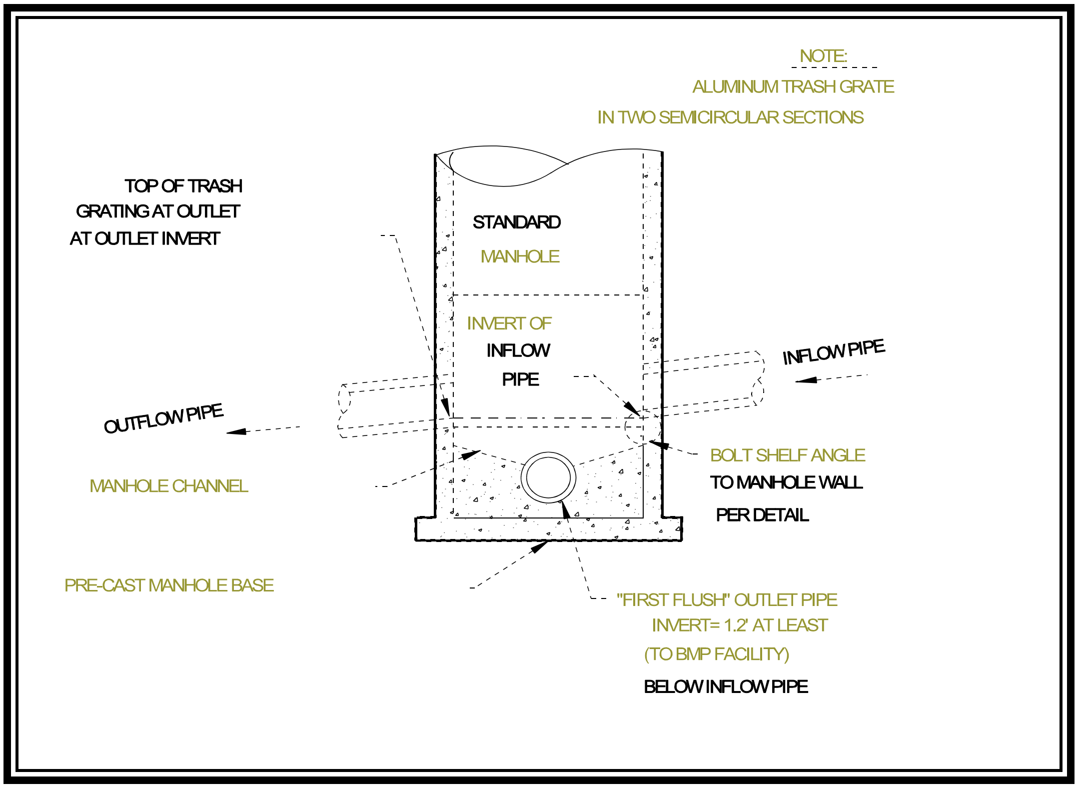
Several types of intermittent sand filter facilities are recognized for stormwater quality management purposes, including ***District of Columbia Underground Vault Filters***, ***Delaware Sand Filters, Austin Full Sedimentation Sand Filters,*** and ***Austin Partial Sedimentation Sand Filters***.

The general design criteria presented below apply to the design of intermittent sand filter facilities for ***water quality control***. This implies that the volume of runoff to be treated is determined by the **water quality volume** (the first 0.5 inches of runoff from the impervious surfaces on the site or drainage shed) and the desired pollutant removal efficiency.

### Isolating the Water Quality Volume

The usual method for isolating the WQV is to construct an isolation/diversion weir in the stormwater channel or pipe, with the elevation of the weir set to allow overflow when the BMP is completely full. Additional runoff greater than the WQV spills over the weir to enter a peak flow rate reducer or exit directly to the storm sewer, minimizing mixing with the water in the BMP. Another approach is to provide a lower pipe to feed the filter until it fills, after which water rises in the slitter manhole and continues down a higher pipe. **Figure 3.12 - 2** illustrates this approach (source: Montgomery County, Maryland).

**FIGURE 3.12 - 2**
***Flow Splitting Manhole Structure***




## Sizing Procedure

The majority of jurisdictions which are employing sand filter BMPs use hydraulic calculations based on Darcy's Law to establish the filter area that will allow flow-through of the treatment volume within the desired time frame, typically 40-48 hours (Austin, 1988, Shaver and Baldwin, 1991, Truong, 1989). Florida uses more complex falling-head computations and allows a drawdown time of up to 72 hours (Livingston, McCarron, Cox, and Sanzone, 1988). However, creating storage for the full WQV in shallow configuration systems may result in a larger filter than the hydraulic calculations would indicate (Alexandria, 1992).

Virginia uses the Austin Sand Filter Formula derived from Darcy's Law by the Austin Environmental and Conservation Services Department to size sand filters (Austin, 1988):

$A_f = I_a H d_f / k(h+d_f)t_f$ where,

$A_f$ = surface area of sand bed (acres or sq. ft.)
$I_a$ = impervious drainage area contributing runoff to the basin (acres or sq. ft.)
H = runoff depth to be treated (ft.)
$d_f$ = sand bed depth (ft.)
k = coefficient of permeability for sand filter (ft/hr)

h = average depth (ft.) of water above surface of sand
media between full and empty basin conditions (½ max. depth)
$t_f$ = time required for runoff volume to pass through filter media (hrs.)

**1. Coefficient of Permeability**

When first installed, the coefficient of permeability of sand filters may be as high as 3.0 ft/hour, but these will typically decrease dramatically after the first few storms. Actual observations of filters in Austin, Texas, established that "ripe" filters stabilized in the range of 0.5-2.7 ft/day for filters with partial sedimentation control (Austin, 1988). This is probably caused by a combination of clogging of some filter pores from sediment loads and initial consolidation of the filter sand. **Figure 3.12 - 3** illustrates the similar rapid decrease in coefficient of permeability as sediment loads accumulated on a sand filter in Denver, Colorado (Urbonas, Doerfer, and Tucker, 1996). Falling head tests on a one year old Delaware Sand Filter in Alexandria, Virginia, resulted in an average coefficient of permeability of 8.5 ft/day (Bell, Stokes, Gavan, and Nguyen, 1995). The Alexandria filter was treating only runoff from pavement surfaces, and the mean input concentration of total suspended solids was only in the range of 75 milligrams/liter (75ppm)(*ibid)*. The Denver runoff, by contrast, had a mean concentration of 400 ppm (Urbonas, Doerfer, and Tucker, 1996), while the filters observed by Austin lacked full sedimentation protection. Use of conservative values for the coefficient of permeability is clearly indicated.

Based on long term observation of existing sand filter basins, Austin uses k values of 3.5 feet per day for systems with full sedimentation pretreatment and 2.0 feet per day for systems with only partial sedimentation pretreatment (full sedimentation pretreatment is defined as complete removal of particles with a diameter equal to or greater than 20 microns). Virginia jurisdictions utilizing intermittent sand filter BMPs have also adopted these values. Full sedimentation may usually be accomplished by capturing the WQV and releasing it to the filter over 24 hours. **Figure 3.12-4** illistrates a full sedimentation basin in Austin. Partial sedmientation basins, such as the one shown on **Figure 3.12-1**, should hold at least 20 percent of the WQV.

**2. Drawdown time**

Both Austin and the Virginia jurisdictions employ a BMP drawdown time ($t_f$) of 40 hours. This allows the filter to fully drain down and dry out to maintain an aerobic environment between storms (filters which remain continually wet may develop anaerobic conditions, under which previously captured iron phosphates may break down and wash out).

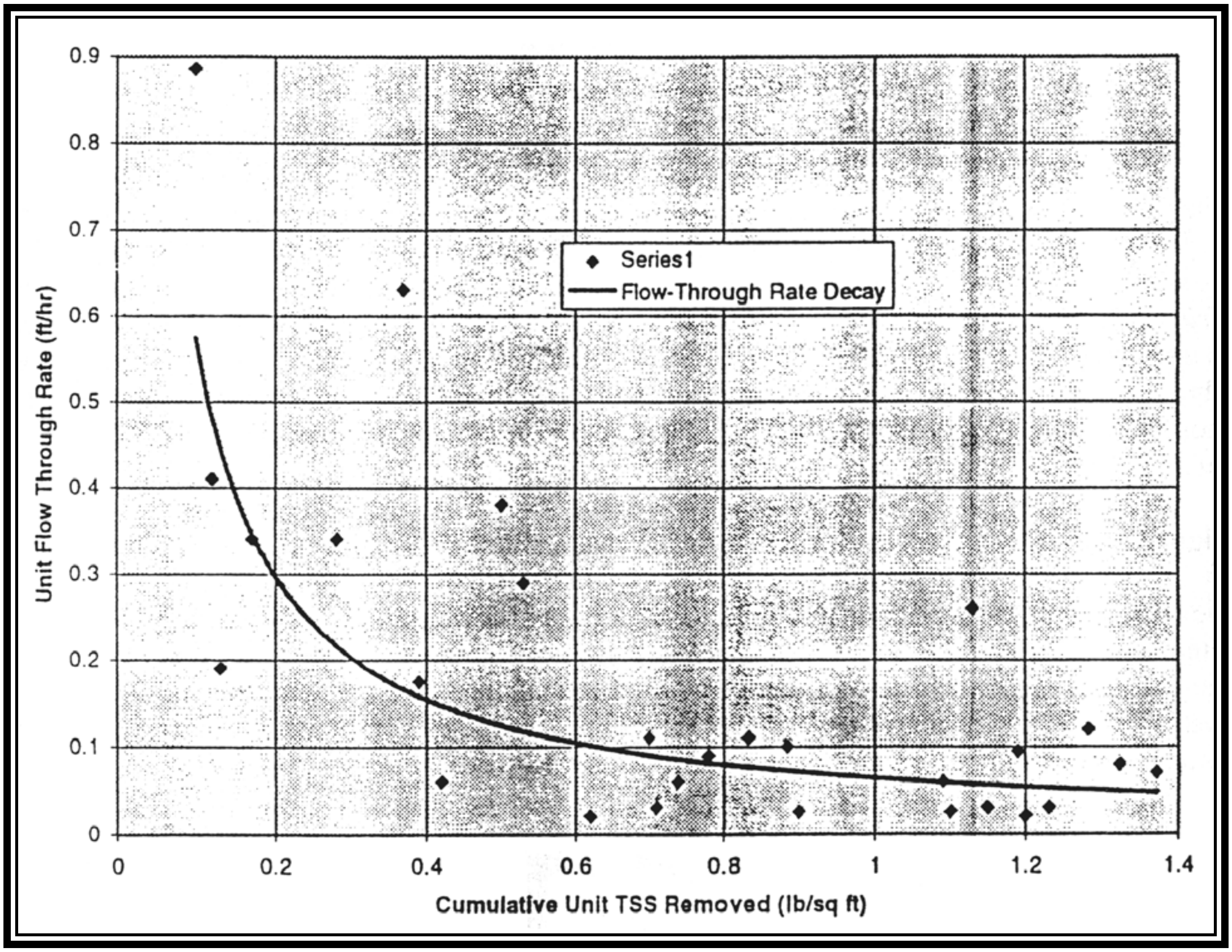
**3. Simplified Filter Formula for Filters with Full Sedimentation Protection**
(Sedimentation Basin containing full WQV with 24-hour drawdown to filter)

With k = 3.5 ft/day (0.146 ft/hour) and $t_f$ = 40 hours, the sand filter formula reduces to:

$$A_{f(FS)} = 310 I_a d_f / (h + d_f)$$

where $A_f$ is in $ft^2$ and $I_a$ is in acres.

**FIGURE 3.12-3**
*Degradation of Hydraulic Conductivity of Denver Sand Filter*




(Source: Urbonas, Doeffler, and Tucker, 1996)

**4. Simplified Filter Formula for Filters with Partial Sedimentation Protection**
(Sediment Chamber containing 20% of WQV with free hydraulic flow to filter)

With k = 2.0 ft/day (.0833 ft/hour) and $t_f$ = 40 hours, the formula reduces to:

$$A_{f(PS)} = 545 I_a d_f / (h + d_f)$$

where $A_f$ is in $ft^2$ and $I_a$ is in acres.

**FIGURE 3.12-4**

***Full Sedimentation Basin on Austin Sand Filter***

## Exclusion of Continuous Flows and Chloronated Flows

Intermittent sand filter BMPs will **NOT** function properly if subjected to continuous or frequent flows. The basic principles upon which they operate assume that the sand filter will dry out and reaerate between storms. If the sand is kept continually wet by such flows as basement sump pumps, anaerobic conditions will develop, creating a situation under which previously captured iron phosphates degrade, leading to **export** of phosphates rather than the intended high phosphorous removal (Bell, Stokes, Gavan, and Nguyen, 1995). It is also essential to **exclude flows containing chlorine and other swimming pool and sauna chemicals** since these will kill the bacteria upon which the principle nitrogen removal mechanisms depend.

***Continuous or frequent flows (such as basement sump pump discharges, cooling water,condensate water, ariesian wells, etc.) and flows containing swimming pool and sauna chemiclals*** *must be* ***EXCLUDED*** *from routing through intermittent sand filter BMPs since such flows will cause the BMP to* ***MALFUNCTION!***

## Checklists

The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

## MINIMUM STANDARD 3.12A

# WASHINGTON D.C. UNDERGROUND VAULT SAND FILTER
## (WET SEDIMENTATION CHAMBER)

### Definition

A Washington D.C. vault sand filter is an underground stormwater sand filter contained in a structural shell with three chambers. The shell may be either precast or cast-in-place concrete, corrugated metal pipe, or fiberglass tanks. This BMP was developed by Mr. Hung V. Truong of the D.C. Environmental Regulation Administration. **Figure 3.12A-1** depicts Mr. Truong's system.

The three feet deep plunge pool in the first chamber and the throat of the second chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves.

The second chamber also contains a typical intermittent sand filter. The filter material consists of gravel, sand, and filter fabric. At the bottom is a subsurface drainage system of pierced PVC pipe in a gravel bed. The primary filter media is 18-24 inches of sand. A layer of plastic reinforced geotextile filter cloth secured by gravel ballast is placed on top of the sand. The top filter cloth is a pre-planned failure plane which can readily be replaced when the filter surface becomes clogged. A dewatering drain controlled by a gate valve must be installed to facilitate maintenance.

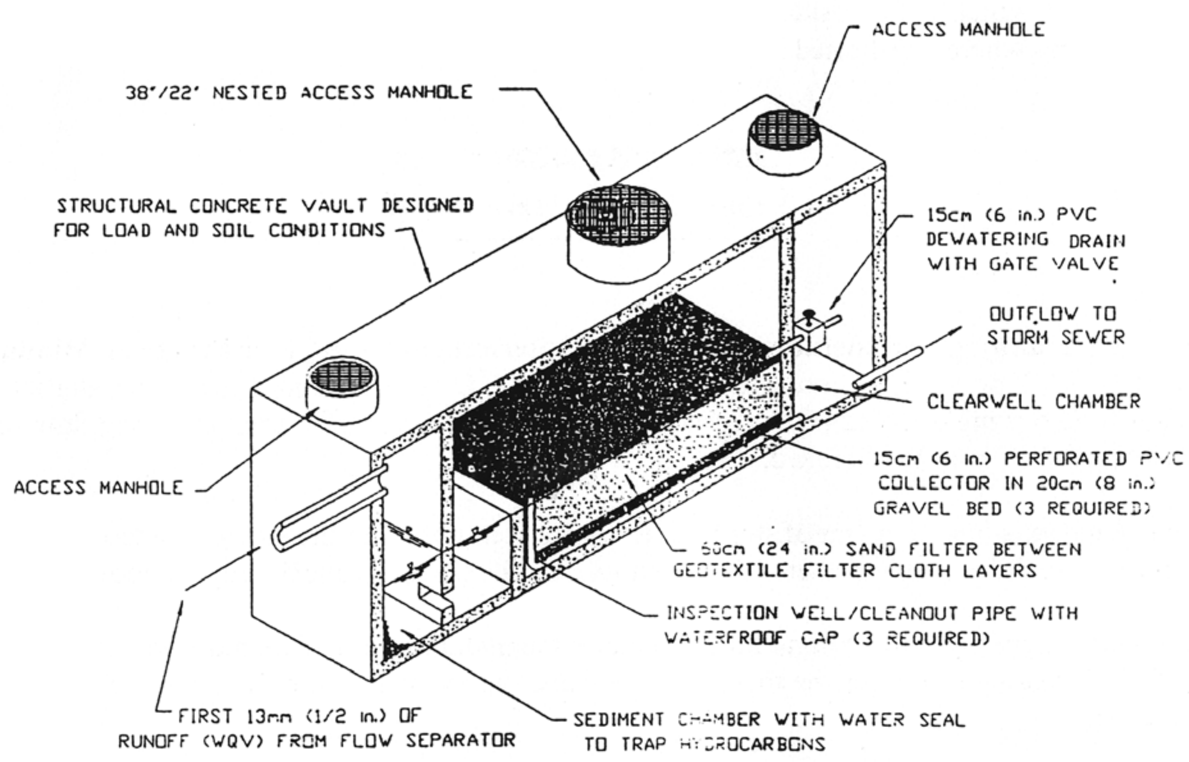
The third chamber, or clearwell, collects the flow from the underdrain pipes and directs it to the storm sewer.

In Virginia, D.C. Sand Filters will normally be placed off-line and be sized to treat the WQV.

### Purpose

D.C. Sand Filters are primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity must be provided.

**FIGURE 3.12A - 1**
*Washington D.C. Underground Vault Sand Filter*




## Conditions Where Practice Applies

D.C. Sand Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. Where possible, runoff treated should come only from impervious surfaces.

Drainage Area

Drainage areas served by one vault filter should be limited to 1.25 acres. For larger drainage sheds, either multiple vault filters or Austin Full Sedimentation Filters (surface or vault) should be utilized.

Development Conditions

D.C. Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

## Planning Considerations

Refer to the **Planning Considerations** for **General Intermittent Sand Filter Practices, Minimum Standard 3.12,** previously discussed in this section. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration (whatever the pooling depth, there must be a minimum of five feet of clearance between the top of the filter and the top slab of the filter shell to allow filter maintenance).

*Sand filter BMPS must **never** be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of D.C. Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

The D.C. Sand Filter is a partial sedimentation protection intermittent sand filter BMP. To compute the minimum area of filter required, utilize the Austin Filter Formula for partial sedimentation treatment:

$$A_{fm(PS)} = \frac{545 I_a d_f}{(h + d_f)}$$

where,

$A_{fm}$ = minimum surface area of sand bed (square feet)
$I_a$ = impervious cover on the watershed in acres
$d_f$ = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

Structural Requirements

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and, certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer and the structural plans require approval by the plan approving jurisdiction.

Design Storm

The inlet design or integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. Since D.C. Sand Filters will be used only as off-line facilities in Virginia, the interior hydraulics of the filter are not as critical as when used as an on-line facility. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable that D.C. Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

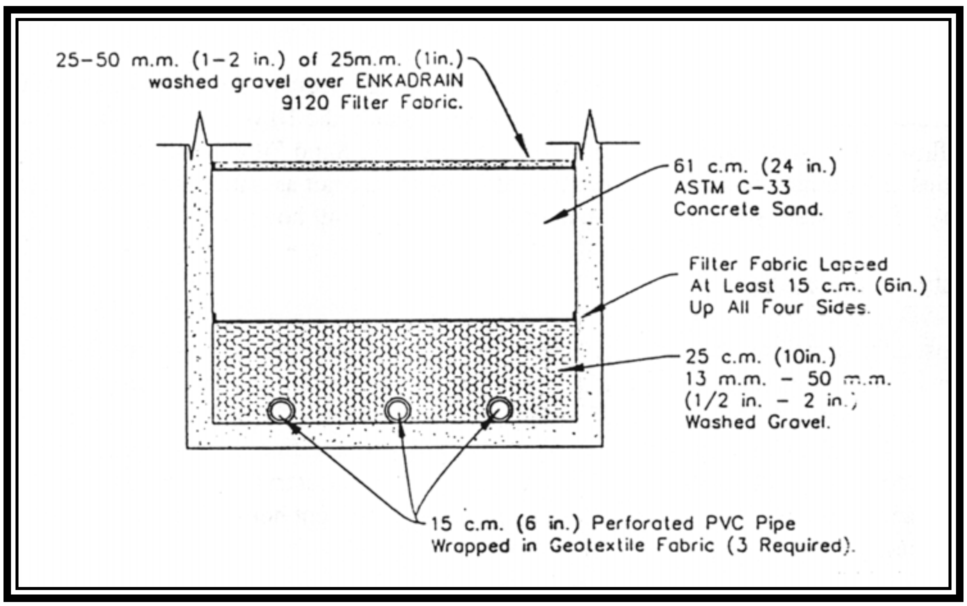
Accessibility and Headroom for Maintenance

Both the sedimentation basin and the filter must be accessible to approriate equipment and vacuum trucks for removing accumulated sediments and trash. The sedimentation basin must be cleaned approximately once per year, and the filter will likely need raking on that frequency to remove trash and restore permeability. When filters are placed in underground vaults, all three chambers must have personnel access manholes and built-in access ladders. **A minimum headspace of 60 inches above the filter is required to allow such maintenance and repair.** A 38-inch diameter maintenance manhole with eccentric nested covers ( a 22-inch personnel access lid inside the 38-inch diameter lid) or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter.

## Construction Specifications

**Figure 3.12A-2** is a cross-section of the filter chamber.

**FIGURE 3.12A - 2**
***D.C. Sand Filter Cross-Section***



Depth of Sedimantation Pool

The sedimentation “plunge pool” must be at least 36 inches deep to properly remove sediment and absorb energy from the incoming flow.

Depth of the Underwater Opening Between Chambers

To preserve an effective hydrocarbon trap, the top of the underwater opening between chambers must be at least 18 inches below the depth of the weir which divides the filter from the pool. To retain sediment in the first chamber, the bottom of the opening should be at least six inches above the floor. The area of the opening should be at least 1.5 times the cross-sectional area of the inflow pipe(s) to assure that the water level remains equal between the first and second chambers.

Total Depth of Filter Cross-Section

The total depth of the filter cross-section must match the height of the weir dividing the sedimentation pool from the filter. Otherwise, a “waterfall” effect will develop which will gouge out the front of the filter media. If a sand filter less than 24 inches is used, the gravel layer must be increased accordingly to preserve the overall filter depth.

Upper Aggregate Layer

The washed aggregate or gravel layer at the top of the filter shall be at least one inch thick and meet ASTM standard specifications (1-inch maximum diameter).

Geotextile Fabrics

The filter cloth layer beneath the upper aggregate layer shall be reinforced by an HDPE or PVC geomatrix (such as ENKADRAIN 9120) and meet the specifications shown in **Table 3.12C-1**. The filter fabric between the sand layer and the collector gravel shall conform to the specifications in **Table 3.12A-2**. The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand** or sand meeting the Grade A fine aggregate gradation standards of Section 202 of the VDOT ***Road and Bridge Specifications.*** The top of the sand filter must be completely level.

**TABLE 3.12A - 1**
***Specifications for Nonwoven Geotextile Fabric on Top of D.C. Sand Filter***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| **Unit Weight** | ASTM D-1777 | Oz./Sq.yd. | 4.3 (minimum) |
| **Flow Rate** | Falling Head Test | Gpm/Sq.ft. | 120 (minimum) |
| **Puncture Strength** | ASTM D-751 (Modified) | Lb. | 60 (minimum) |
| **Thickness** | -- | In. | 0.08 (minimum) |

**Table 3.12A - 2**
***Specifications for Nonwoven Geotextile Fabric Beneath Sand in D.C. Filter***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| **Unit Weight** | -- | Oz./sq.yd. | 8.0 (min.) |
| **Filtration Rate** | -- | In/sec | 0.08 (min.) |
| **Puncture Strength** | ASTM D-751 (Modified) | Lb. | 125 (min.) |
| **Mullen Burst Strength** | ASTM D-751 | Psi | 400 (min.) |
| **Equiv. Opening Size** | U.S. Standard Sieve | No. | 80 (min.) |
| **Tensile Strength** | ASTM D-1682 | Lb. | 300 (min.) |

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes.

Underdrain Piping

The underdrain piping consists of three 6-inch schedule 40 or better polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations should be 3/8 inch, and each row of perforations shall contain at least six (6) holes. Maximum spacing between rows of perforations shall be six (6) inches.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface, e.g. the top layer of gravel.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12A-2** above.

Dewatering Drain

When the filter is placed in an underground vault, A 6-inch dewatering drain controlled by a gate valve shall be installed between the filter chamber and the clearwell chamber with its invert at the elevation of the top of the filter. The dewatering drain penetration in the chamber dividing wall shall be sealed with a flexible strip joint sealant which swells in contact with water to form a tight pressure seal.

Access Manholes

When the filter is installed in an underground vault, access to the headbox (sediment chamber) and the clearwell shall be provided through at least 22-inch manholes. Access to the filter chamber shall be provided by a rectangular dood (minimum size: 4 feet by four feet) of sufficient strength to carry prospective imposed loads or by a manhole of at least 3- inch diameter with an offset concentric 22-inch lid (Neenah R-1741-D or equivalent).

Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

**No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation.** Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

**After completion of the filter shell but before placement of the filter layers**, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

**After placement of the collector pipes, gravel, and lower geotextile layer**, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

Portland Cement Concrete

Concrete liners may be used for sedimentation chambers and for sedimentation and filtration basins. Concrete shall be at least five (5) inch thick Class A3 defined in the Virginia Department of Transportation *Road and Bridge Specifications.*

## Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

The water level in the filter chamber shall be monitored by the owner on a quarterly basis and after every large storm for the first year after completion of construction and a log shall be maintained of the results indicating the rate of dewatering after each storm and the water depth for each observation. Once the governing jurisdiction staff indicates that satisfactory performance of the structure has been demonstrated, the monitoring schedule can be reduced to an semiannual basis.

The BMP shall be inspected annually by representatives of the owner and the governing jurisdiction to assure continued proper functioning.

Sediment Chamber Pumpout

The sediment chamber must be pumped out halfway through the inspection cycle (e.g. after six months) and after each joint owner-governing jurisdiction annual inspection. If the chamber contains an oil skim, it should be removed by a firm specializing in oil recovery and recycling. The remaining material may then be removed by vacuum pump and disposed of in an appropriate landfill. **After each cleaning, refill the first chamber to a depth of three feet with clean water to reestablish the water seals**.

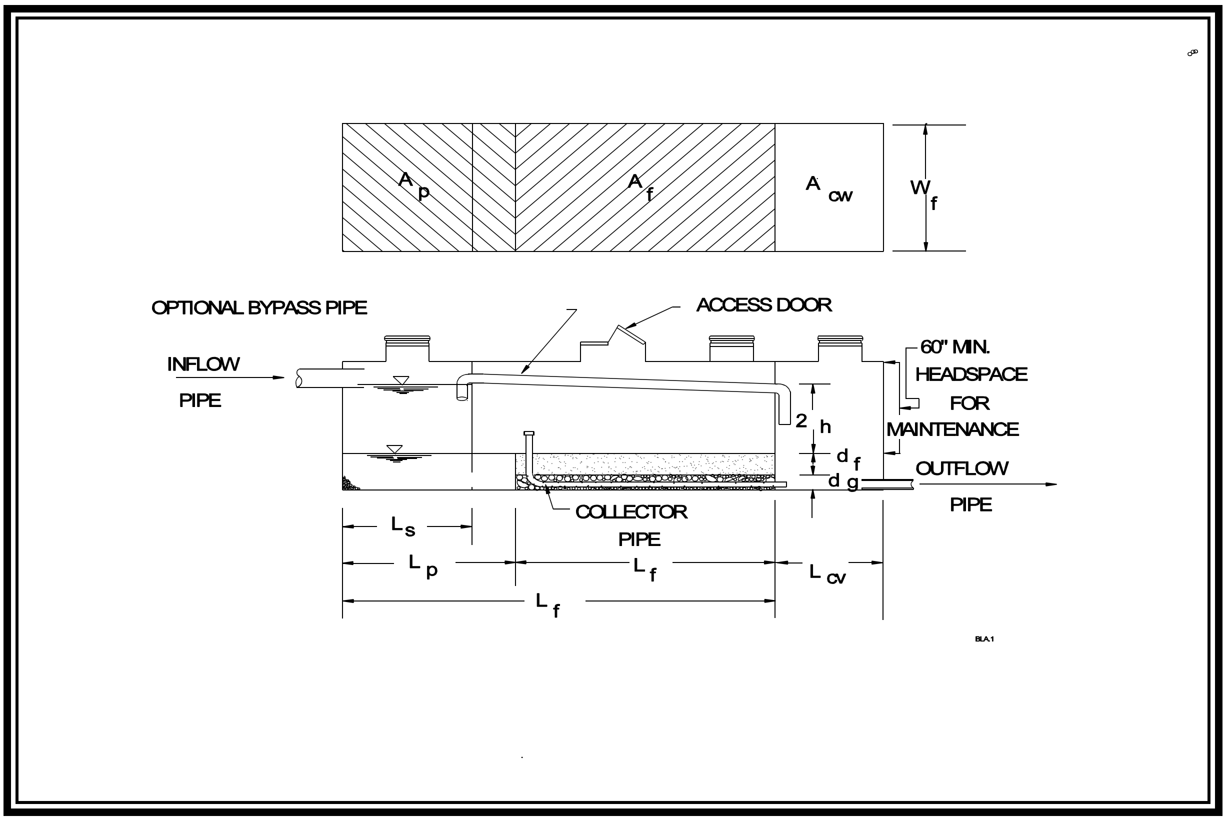
When the filter will no longer draw down within the required 40-hour period, the top layer of filter cloth and ballast gravel must be removed and replaced with new materials conforming to the original specifications. Any discolored or sediment contaminated sand shall also be removed and replaced.

## Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by the D.C.Sand Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used.

**Figure 3.12A-3** shows the dimensional relationships for a D.C. Sand Filter.

**FIGURE 3.12A - 3**
***Dimensional Relationships for a D.C. Sand Filter***



Standard Design Logic

Employ the following design logic to design D.C. Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site ($I_a$ in acres), the water quality volume to be treated (WQV in $ft.^3 = 1816\ I_a$), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth (($d_f$) and determine the maximum achievable ponding depth over the filter (2h).

3. Compute the Minimum Area of the Sand Filter ($A_{fm}$)

To compute the area of the filter, use the formula:

$$A_{fmPS} = \frac{545 I_a d_f}{(h + d_f)}$$

$A_{fm}$ = minimum surface area of sand bed (square feet)
$I_a$ = impervious cover on the watershed in acres
$d_f$ = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

4. Select Filter Width and Compute Filter Length and Adjusted Filter Area

Considering site constraints, select the Filter Width ($W_f$). Then compute the Filter Length ($L_f$) and the Adjusted Filter Area ($A_f$)

$$L_f = A_{fm}/W_f$$

$$A_f = W_f \times L_f$$

Note: From this point forward, computations assume a rectangular filter.

5. Compute the Storage Volume on Top of the Filter ($V_{Tf}$)

$$V_{Tf} = A_f \times 2h$$

6. Compute the Storage in the Filter Voids ($V_v$)
(Assume 40% voids in filter media)

$$V_v = 0.4 \times A_f \times (d_f + d_g)$$

7. Compute Flow Through Filter During Filling ($V_Q$)
(Assume 1-hour to fill per D.C. practice)

$$V_Q = \frac{kA_f(d_f + h)}{d_f} \text{ ; use } k = 2 \text{ ft./day} = 0.0833/\text{hr.}$$

8. Compute Net Volume to be Stored Awaiting Filtration ($V_{st}$)

$$V_{st} = WQV - V_{Tf} - V_v - V_Q$$

9. Compute Length of the Permanent Pool (Lpm)

$$Lpm \quad \frac{V_{st}}{(2h \times W_f)}$$

10. Compute Minimum Length of the Sediment Chamber (Lsc)
(to contain 20% of WQV per Austin practice)

$$L_{sm} = \frac{0.2WQV}{(2h \times W_f)}$$

11. Set Final Length of the Permanent Pool ($L_p$)

If $L_{pm} \geq L_{sm} + 2$ ft., make $L_p = L_{pm}$

If $L_{pm} < L_{sm} + 2$ ft., make $L_p = L_{sm + 2 \text{ ft.}}$

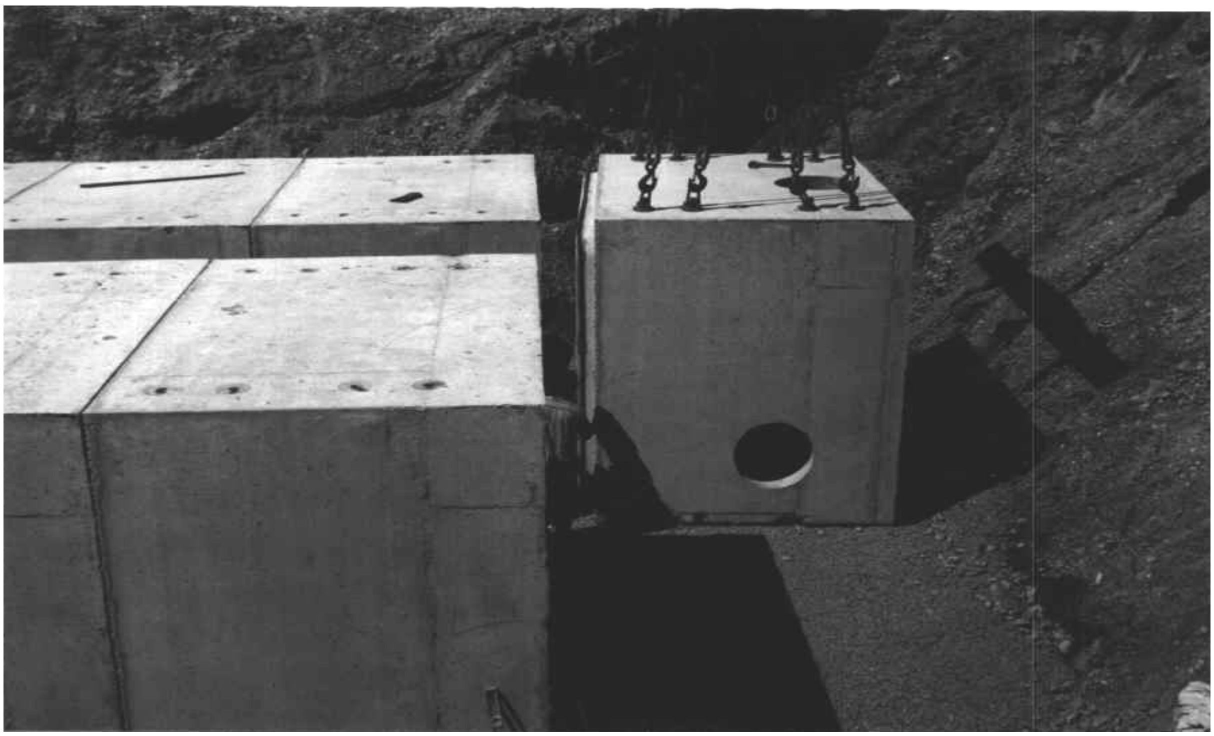
It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

Set the length of the clearwell ($L_{cw}$) for adequate maintenance and/or access for monitoring flow rate and chemical composition of the effluent (minimum = 3 ft.)

Minimizing Filter Shell Costs

Underground vault sand filter costs have been widely varying because many developers have simply had their foundation contractors cast the vault in place. Each installation therefore became a prototype with associated costs and overhead. Precast manufacturers currently offer precasting services for D.C. and other types of sand filter vaults, which should stabilize underground vault costs. **Figure 3.12A-4** is a photograph of a segmented precast filter shell installation in Alexandria.

**FIGURE 3.12A - 4**
***Installing Precast D.C. Sand Filter Shell in Alexandria***

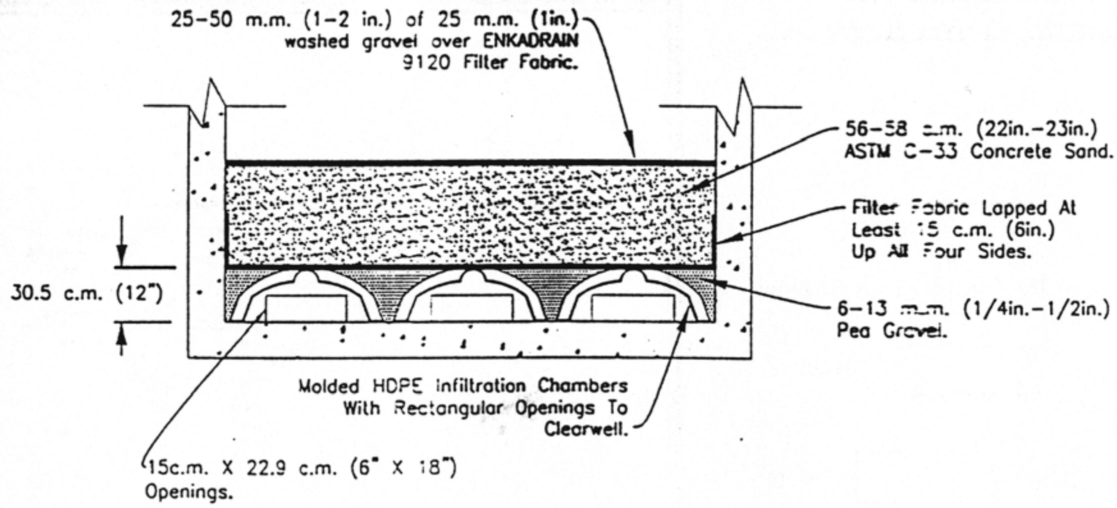


(Photo Courtesy of Rotondo Precast, Fredericksburg, Virginia)

## Checklists

Worksheet 3.12A is for use in sizing calculations for D.C. Sand Filters. The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

**FIGURE 3.12A - 5**
***D.C. Filter Cross-Section with HDPE Infiltration Chamber Collector System***

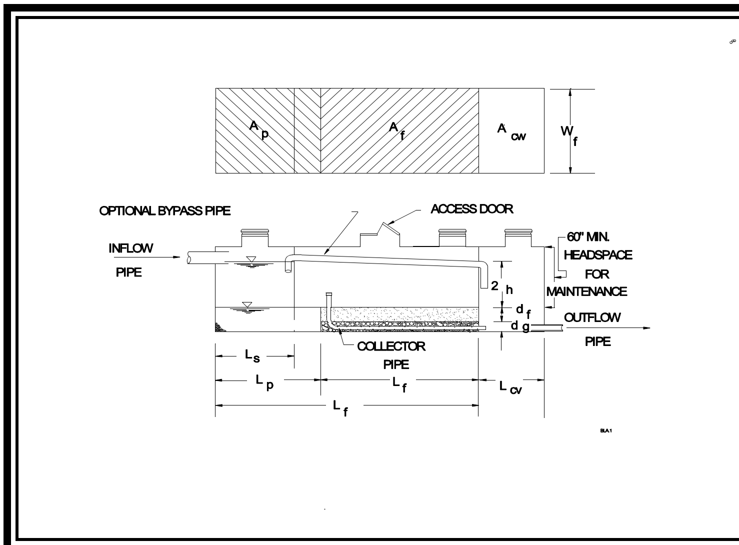


**WORKSHEET 3.12A**
**SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER**
Page 1 of 4

**Part 1: Select maximum ponding depth over filter**:

2h = _______ ft;

h = [ ] ft




From Pollutant Load Sheets:

$I_a$ = [ ] acres

WQV = [ ] $ft^3$

Outflow by gravity possible ___

Effluent pump required __

**Part 2: Compute Minimum Area of Filter ($A_{fm}$):**

$$A_{fm} = \frac{545 I_a d_f}{(d_f + h)}$$

= [545 x _______ x _______] / [_______ + _______]

= [ ] $ft^2$

**Part3: Considering Site Constraints, Select Filter Width ($W_f$) and Compute Filter Length ($L_f$) and Adjusted Filter Area ($A_f$):**

$W_f$ = [ ] ft;

**WORKSHEET 3.12A**
**SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER**
Page 2 of 4

$L_f = A_{fm} / W_f$

= ________/________

= ______, say [ ] ft

$A_f = W_f \times L_f$ = ________ x _________

= [ ] ft$^2$

**Part 4: Compute the Storage Volume on Top of the Filter($V_{Tf}$)**

$V_{Tf} = A_f \times 2h$ = ________x _________

= [ ] ft$^3$

**Part 5: Compute Storage in Filter Voids ($V_v$):**
(Assume 40% voids in filter media)

$V_v = 0.4 \times A_f \times (d_f + d_g)$

= 0.4 x ________ x (________ + ________)

= [ ] ft$^3$

**Part 6: Compute Flow Through Filter During Filling Period ($V_Q$):**
(Assume 1-hour to fill per D.C. practice)

$V_Q = \frac{kA_f(d_f + h)}{d_f}$ ; use k = 2 ft/day = 0.0833 ft/hr

= [0.0833 x ________ x (_________ + ________)]/__________

= [ ] ft$^3$

**WORKSHEET 3.12A**
**SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER**
Page 3 of 4

**Part 7: Compute Net Volume to be Stored Awaiting Filtration ($V_{st}$):**

$V_{st} = WQV - V_{Tf} - V_v - V_Q$

= _______ - _______ - _______ - _______

= [ ] $ft^3$

**Part 8: Compute Minimum Length of Permanent Pool ($L_{pm}$):**

$L_{pm} = \frac{V_{st}}{(2h \times W_f)}$ = _______ / (_______ x _______)

= [ ] ft

**Part 9: Compute Minimum Length of Sediment Chamber ($L_{sm}$)**
(to contain at least 20% of WQV per Austin practice)

$L_{sm} = \frac{0.2WQV}{(2h \times W_f)}$ = _______ /_______

= [ ] ft

**Part 10: Set Final Length of Permanent Pool ($L_p$)**

$L_{sm}$ + 2ft = ________ + 2 = [ ] ft

If $L_{pm} \geq L_{sm}$ + 2ft, Make $L_p = L_{pm}$ [ ] = ft

If $L_{pm} < L_{sm}$ + 2ft, make $L_p = L_{sm}$ +2ft = [ ]

**WORKSHEET 3.12A**
**SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER**
Page 4 of 4

**Part 11: Set Length of Clearwell ($L_{cw}$) for Adequate Maintenance Access (Minimum = 3 ft) and Compute Final Inside Length ($L_{ti}$):**

$L_{cw}$ = [ ] ft;

Sum of interior partition thicknesses ($t_{pi}$) = ________ ft

$L_{ti} = L_f + L_p + L_{cw} + t_{pi}$

= ________ + ________ + ________ + ________

= [ ] ft

**Part 12: Design Effluent Pump if Required**

Since pump must be capable of handling flow when filter is new, use k = 12 feet/day = 0.5 ft/hr

$$Q = \frac{kA_f(d_f + h)}{d_f}$$

= [0.5 x ________ x (________ + ________)] /________

= [ ] ft$^3$/hr ; /3600 = [ ] cfs;

x 448 = [ ] gpm

**Part 13: Design Structural Shell to Accommodate Soil and Load conditions at Site:**

It may be economical to adjust final dimensions upward to correspond with standard precast structures or to round dimensions upward to simplify layout during construction.

## MINIMUM STANDARD 3.12B

# DELAWARE SAND FILTER (DSF) SYSTEMS

### Definition

Mr. Earl Shaver of the Delaware Department of Natural Resources and Environmental Control has developed a surface sand filter system for use in Delaware (Shaver and Baldwin, 1991)

As originally conceived, the Delaware Sand Filter is an **on-line** facility processing all stormwater exiting the treated site up to the point that its overflow limit is reached (Delaware provides for treating the first one inch of runoff). However, when employed in Virginia, it will usually be provided with an integral flow-splitter to isolate and treat the Water Quality Volume.

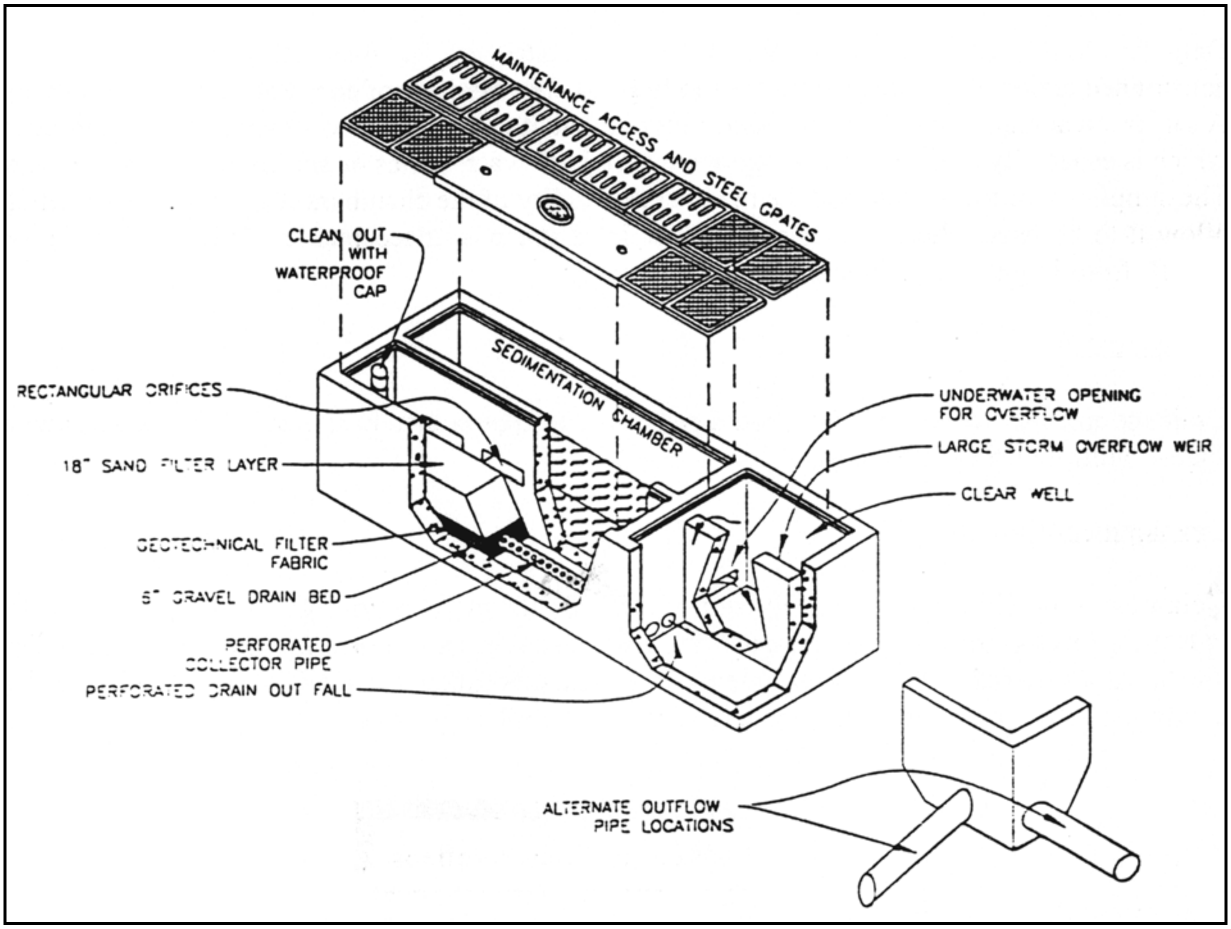
**Figure 3.12B-1** shows a schematic drawing of the Delaware Sand Filter as used in Virginia. The system consists of two parallel concrete trenches connected by close-spaced wide notches in the wall dividing the trenches. The trench adjacent to the site being served is the sedimentation chamber. When accepting sheet flow, it is fitted with a grated cover. Concentrated stormwater may also be conveyed to the chamber in enclosed storm drain pipes. The second chamber, which contains the sand filter, is always fitted with a solid cover.

Storm flows enter the sedimentation chamber through the grates, causing the sedimentation pool to rise and overflow into the filter chamber through the weir notches in the dividing wall, assuring that the water to be treated **arrives at the filter as sheet flow**. This is essential to prevent scouring out the sand. The permanent pool in the sedimentation chamber is dead storage, which inhibits resuspension of particles that were deposited in earlier storms and prevents the heavier sediments from being washed into the filter chamber. Floatable materials and hydrocarbon films, however, may reach the filter media through the surface outflow.

The second trench contains at least 18 inches of ASTM C-33 Concrete Sand . When used in Virginia, an underdrain capability must be provided. Runoff percolates through the sand to the underdrain (s) and exits into the flow splitter/clearwell.

A transverse flow-splitter/clearwell at the lower end of the structure collects treated effluent and overflow and conveys the water to the storm sewer. When the filter shell fills with the Water Quality Volume, excess flow is forced through the underwater opening from the sedimentation chamber to the “wet” section of the clearwell to overflow the weir to the outflow pipe chamber. Floating trash and hydrocarbons are retained in the sedimentation chamber by this “trap.”

**FIGURE 3.12B - 1**
*Precast Delaware Sand Filter as Used in Virginia*




## Purpose

Delaware Sand Filters primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity must be provided.

## Conditions Where Practice Applies

Delaware Sand Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. A major advantage of the Delaware Sand Filter is that it can be installed in shallow configurations, which is especially critical in flatter regions where high water tables or shallow storm sewers exist. The simplicity of the system and the ready accessibility of the chambers for periodic maintenance allow it to be used where a filter built in confined space is unacceptable. Where possible, only runoff from impervious surfaces should be treated.

Drainage Area

Drainage areas served by one filter should be limited to approximately one acre. For larger drainage sheds, multiple DSFs may be used.

Development Conditions

Delaware Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

## Planning Considerations

Refer to the **Planning Considerations** for **General Intermittent Sand Filter Practices, Minimum Standard 3.12,** previously discussed in this section. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration.

*Sand filter BMPS must **never** be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of Delaware Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

Because of the shallow configuration of this BMP, resulting in low levels of hydraulic head above the filter, application of the usual partial sedimentation filter formula may not create enough storage volume to contain the WQV. With the dimensional relationships shown in **Figure 3.12B-2** and k = 2.0 ft/day, the required DSF filter area to contain the WQV may be written as follows:

$$A_f = \frac{1816 I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

where:

$A_f$ = the **area of the filter** in sq.ft.
$I_a$ = the impervious area on the watershed in acres
h = 1/2 the maximum ponding depth over the filter (ft.)

If the maximum ponding depth above the filter (2h) is less than 2.67 feet (2'-8"), the WQV storage requirement governs and the above foumula must be used to size the filter (Alexandria, 1992). If the the maximum ponding depth above the filter (2h) is 2.67 feet or greater, use the partial sedimentation filter formula:

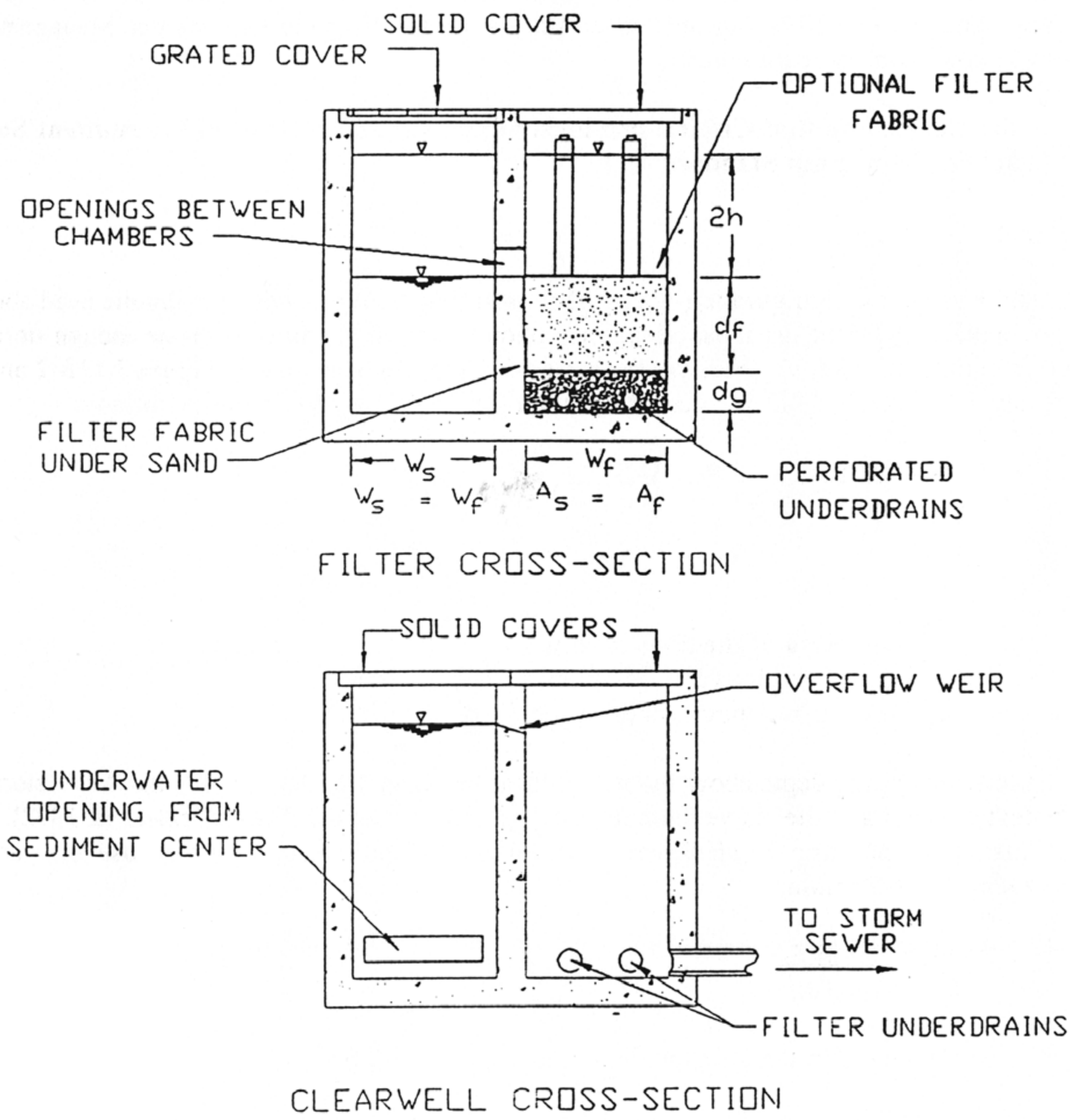
$$A_f = \frac{545 I_a d_f}{(h + d_f)}$$

Where $d_f$ = depth of the filter media in ft. (1.5-2.0)

Delaware and Virginia make the area of the sediment chamber($A_s$) equal the area of the filter:

$$A_f = A_s$$

**FIGURE 3.12B- 2**
*Dimensional Relationships for Delaware Sand Filter*



Structural Requirements

When the system is placed in a street or parking lot, it must be designed to support traffic wheel loads. When placed completely off the pavement, lower structural loads will be involved. The structure must be designed by a licensed professional engineer, and the design must be approved by the governing jurisdiction.

Design Storm

The inlet integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable that Delaware Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

## Construction Specifications

Upper Aggregate Layer

Some jurisdictions require a layer of filter cloth and gravel on top of the filter. When used, the washed aggregate or gravel layer at the top of the filter shall be one inch thick and meet ASTM standard specifications (1 inch maximum diameter.)

Geotextile Fabrics

When used, the filter fabric beneath the one-inch layer of gravel on top of the filter shall be Enkadrain 9120 filter fabric or equivalent with the specifications shown in **Table 3.12B - 1**.

**Table 3.12B - 1**
***Specifications for Nonwoven Geotextile Fabric on Top of Delaware Sand Filter***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| **Unit Weight** | ASTM D-1777 | Oz./sq.yd. | 4.3 (min.) |
| **Flow Rate** | Falling Head Test | Gpm/sq.ft. | 120 (min.) |
| **Puncture Strength** | ASTM D-751 (Modified) | Lb. | 60 (min.) |
| **Thickness** | -- | In. | 0.8 (min.) |

In instances where heavy hydrocarbon loadings are expected, a layer of activated carbon impregnated filter fabric such as Enkadrain PF-3 may be advantageous. When used, a plan to dispose of the hydrocarbon laden used filter fabric must be approved by the applicable jurisdiction prior to placing the sand filter in service.

The filter cloth layer beneath the sand shall conform to the specifications shown in **Table 3.12B-2**.

**Table 3.12B - 2**
***Specifications for Nonwoven Geotextile Fabric Beneath Sand in Delaware Sand Filter***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| **Unit Weight** | -- | Oz./sq.yd. | 8.0 (min.) |
| **Filtration Rate** | -- | In/sec | 0.08 (min.) |
| **Puncture Strength** | ASTM D-751 (Modified) | Lb. | 125 (min.) |
| **Mullen Burst Strength** | ASTM D-751 | Psi | 400 (min.) |
| **Equiv. Opening Size** | U.S. Standard Sieve | No. | 80 (min.) |
| **Tensile Strength** | ASTM D-1682 | Lb. | 300 (min.) |

The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand.** The top of the sand filter must be completely level. No grade is allowable.

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes. The gravel and the sand layer above must be separated by a layer of geotextile fabric meeting the specification listed above.

Underdrain Piping

When round perforated pipes are used, the underdrain piping shall consist of a minimum of two (2) schedule 40 or better four (4) inch polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations shall be 3/8 inch, and each row of perforations shall contain at least four (4) holes. Maximum spacing between rows of perforations shall be six (6) inches.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12B - 2** above.

Alternative Underdrains

Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles shall normally be in two-foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel sizes on all four sides. Sections of tile may be cast in the dividing wall between the filter and the clearwell to provide shallow outflow oricices. Flat perforated drainage piping such as AdvantEdge® may also be used to reduce the depth of filter. Another approach is to raise a grate on small masonary units above the floor of the shell, lay a layer of PVC or polyethelene geomatrix on the grate to spread the load, and install the filter cloth and sand above this matting; molded HDPE infiltration chambers may also be used as shown in **Figure 3.12A-5.** The entire bottom of the filter shell thus becomes a collector channel. When the shell bottom is so used, it shall have a minimum slope of 1/8 inch per foot (1%).

Weepholes

In addition to the underdrain pipes, weepholes may be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes shall be three (3) inches in diameter. Minimum spacing shall be nine (9) inches center to center. The openings on the filter side of the dividing wall shall be covered to the width of the trench with 12 inch high plastic hardware cloth of 1/4 inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of 6 inches back under the bottom stone.

Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

**No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation.** Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

**After completion of the filter shell but before placement of the filter layers**, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

**After placement of the collector pipes, gravel, and lower geotextile layer**, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

Grates and Covers

When placed in traffic lanes, grates and covers must withstand H-20 wheelloadings. Use of standard Virginia Department of Transportation (VDOT) grates (Grate D1-1) will often be most cost-effective. Where allowed by local jurisdictions, galvanized steel bar grates are economical.

Portland Cement Concrete

Portland Cement concrete used for the trench structure shall conform to the A3 specification of the Virginia Department of Transportation ***Road and Bridge Specifications***, latest edition.

## Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

During the first year of operation, the cover grates or precast lids on the chambers must be removed quarterly and a joint owner-jurisdiction inspection made to assure that the system is functioning. Once the jurisdiction inspectors are satisfied that the system is functioning properly, this inspection may be made on an annual basis for other than auto-related activities.

Sediment Chamber Pumpout

The sediment chamber must be pumped out when the joint owner-jurisdiction determines that . If the chamber contains an oil skim, it should be removed by a firm specializing in oil recovery and recycling. The remaining material may then be removed by vacuum pump and disposed of in an appropriate landfill. **After each cleaning, refill the first chamber with clean water to reestablish the water seals to the clearwell.**

Sand Filter

When deposition of sediments in the filtration chamber indicate that the filter media is clogging and not performing properly, sediments must be removed (a small shovel may be all that is necessary) along with the top two to three inches of sand. The coloration of the sand will provide a good indication of what depth of removal is required. Clean sand must then be placed in the filter to restore the design depth. Where a layer of geotechnical fabric overlays the filter, the fabric shall be rolled up and removed and a similar layer of clean fabric installed. Any discolored sand shall also be removed and replaced. Disposal of petroleum hydrocarbon contaminated sand or filter cloth should be coordinated with the appropriate environmental official of the local jurisdiction. On filters which employ an upper geotextile layer and ballast, the top layer of filter cloth and ballast gravel must be removed and replaced with new materials conforming to the original specifications when the filter will no longer draw down within the required 40-hour period. Any discolored or sediment contaminated sand shall also be removed and replaced with sand meeting the original specifications (ASTM C-33 Concrete Sand).

Concrete Shell Inspection

Concrete will deteriorate over time, especially if subjected to live loads. The concrete shell, risers, etc., must be examined during each annual inspection to identify areas that are in need of repair, and such repairs must be promptly effected.

Grass Clippings

Grass clippings from landscape areas on the drainage watershed flowing into the DSF must be bagged and removed from the site to prevent them washing into and contaminating the sediment chamber and filter.

Trash Collection

Trash collected on the grates protecting the inlets shall be removed no less frequently than weekly to assure preserving the inflow capacity of the BMP.

## Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by the Delaware Sand Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used. **Figure 3.12B-2** shows the dimensional relationships required to compute the design.

Standard Design Logic

Employ the following design logic to design Delaware Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site ($I_a$ in acres), the water quality volume to be treated (WQV in $ft.^3 = 1816\ I_a$), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth (($d_f$) and determine the maximum achievable ponding depth over the filter (2h).

3. Calculate the Required Surface Areas of the Chambers

If the maximum ponding depth above the filter (2h) is less than 2.67 feet (2'-8"), the WQV storage requirement governs and the above foumula must be used:

$$A_f = \frac{1816 I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

where:

$A_f$ = the **area of the filter** in sq.ft.

$I_a$ = the impervious area on the watershed in acres

h = 1/2 the maximum ponding depth over the filter (ft.)

If the the maximum ponding depth above the filter (2h) is 2.67 feet or greater, use the partial sedimentation filter formula:

$$A_f = \frac{545 I_a d_f}{(h + d_f)}$$

where:

$d_f$ = depth of the filter media in ft. (1.5-2.0)

Delaware and Virginia make the area of the filter equal the area of the sediment chamber:

$$A_f = A_s$$

4. Establish Dimensions of the Facility

Site considerations usually dictate the final dimensions of the facility. Sediment trenches and filter trenches normally be 18-30 inches wide. Use of standard VDOT D1-1 grates requires a trench width of 26". Some jurisdictions restrict the maximum allowable trench width to 36 inches.

Minimizing Filter Shell Costs

Underground vault sand filter costs have been widely varying because many developers have simply had their foundation contractors cast the vault in place. Each installation therefore became a prototype with associated costs and overhead. Precast manufacturers currently offer precasting services for D.C. and other types of sand filter vaults, which should stabilize underground vault costs. **Figure 3.12B3** is a photograph of a segmented precast shell installation in Alexandria.

**FIGURE 3.12B - 3**
***Installing Precast Delaware Sand Filter Shell in Alexandria, Virginia***

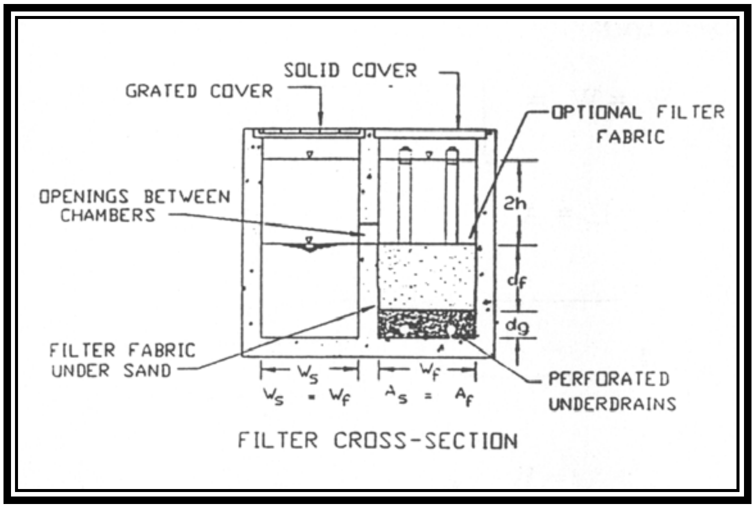
(Photo Courtesy of Rotondo Precast, Fredericksburg, Virginia)

## Checklists

**Worksheet 3.12B** is for use in sizing calculations for Delaware Sand Filters. The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

**WORKSHEET 3.12B**
**SIZING COMPUTATIONS FOR STANDARD DELAWARE SAND FILTER**
Page 1 of 2

**Part 1: Select maximum ponding depth over filter**:




2h = _______ft;

h = [ ] ft

From Pollutant Load Sheets:

$I_a$ = [ ] acres

WQV = [ ] $ft^3$

Outflow by gravity possible____; Effluent pump required _____

**Part 2: Compute Minimum Area of Filter ($A_{fm}$) and Sediment Pool ($A_{sm}$):**

**a)** If 2h ≥ 2.67 feet, use the formula:

$$A_{sm} = A_{fm} = \frac{545 I_a d_f}{(d_f + h)}$$

= [545 x ______ x ______] / [______ + ______]

= [ ] $ft^2$

**b)** If 2h < 2.67 feet, use the formula:

$$A_{sm} = A_{fm} = \frac{1816\ I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

= ________ / [(4.1 x ________) + 0.9]

= [ ] $ft^2$

**WORKSHEET 3.12B**
**SIZING COMPUTATIONS FOR STANDARD DELAWARE SAND FILTER**
Page 2 of 2

**Part 3: Considering Site Constraints, Select Filter Width ($W_f$) and Sediment Pool Width ($W_s$) and Compute Filter Length ($L_f$) and Adjusted Filter Area ($A_f$) and Sediment Chamber Area ($A_s$):**

$W_s = W_f =$ [ ] ft;

$L_s = L_f = A_{fm} / W_f$

= _________ /_________

= _________, [ ] say ft

$A_s = A_f = W_f \times L_f =$ _________ x _________

= [ ] $ft^2$

**Part 4: Design Structural Shell to accommodate Soil and Load Conditions at Site**:

(Separate computations by a structural engineer).

**Part 5: Design Effluent Pump if Required**:

Since pump must be capable of handling flow when filter is new, use k = 12 feet/day = 0.5 ft/hr

$$Q = \frac{kA_f(d_f + h)}{d_f}$$

= [0.5 x _________ x (_________ + ________)]/_________

= [ ] $ft^3$/hr ; /3600 [ ] = cfs;

x 448 = [ ] gpm

## MINIMUM STANDARD 3.12C

# AUSTIN SURFACE SAND FILTER SYSTEMS

### Definition

The City of Austin, Texas, hase been using open basin intermittent sand filtration BMPs for treating stormwater runoff since the early 1980's. The Austin program is managed by the Environmental and Conservation Services Department, which has published design criteria in their *Environmental Criteria Manual* (Austin, 1988). Austin places heavy emphasis on pretreating the stormwater runoff in a sediment trapping presettling basin to protect the filter media from excessive sediment loading. The particles selected by Austin for complete removal in the full sedimentation protection basins are those which are greater than or equal in size to silt with a particle diameter of 0.00007 foot (20 microns) and a specific gravity of 2.65.

**Figure 3.12C-1** illustrates an Austin Full Sedimantation Sand Filter application at a shopping center. In this system the sedimentation structure is a concrete basin designed to hold the entire WQV and then release it to the filtration basin over a 24-hour draw-down period. **Figure 3.12C-2** shows an alternative design which allows a smaller sedimentation chamber (20 percent of the WQV) while increasing the filter size to compensate for increased clogging of the filter media. Although the systems shown utilize concrete basins, a sediment pond and a geomembrane-lined filter built directly into he ground may be used where terrain and soil conditions allow.

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### Purpose

Austin Sand Filters are used primarily for water quality control. However, they do provide detention and slow release over time of the WQV. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon the site conditions. However, in cases where quantity detention beyond the volume of the WQV is required, an attractive alternative may well be to utilize a combined detention basin/pre-settling basin configuration, with the controlled release of the entire stored volume to the sand filter facility.

**FIGURE 3.12C - 1**
***Austin Full Sedimentation Sand Filter System at Barton Ridge Plaza***

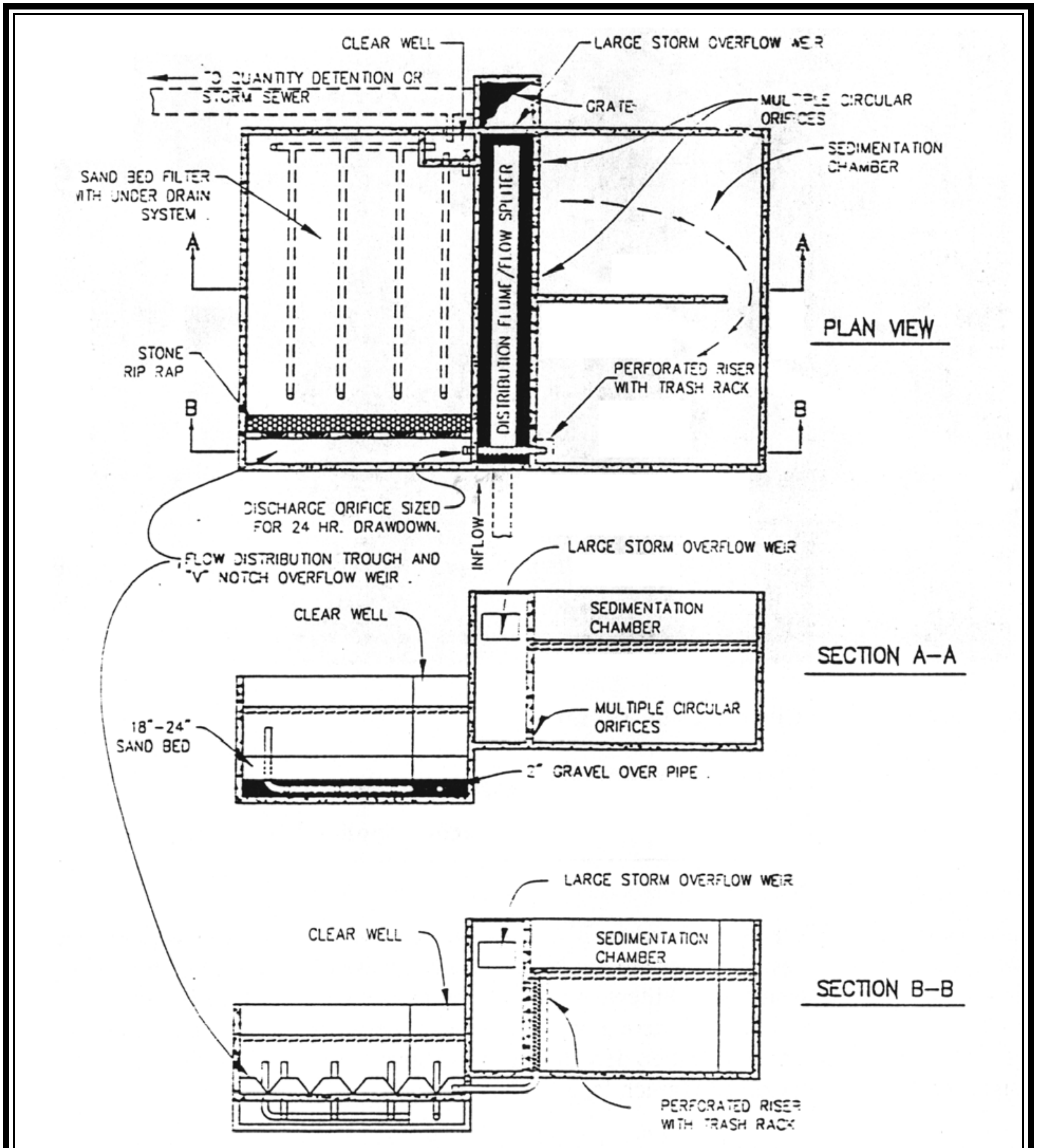


**FIGURE 3.12C - 2**
***Sedimentation Basin of Jolleyville Partial Sedimentation System***

(Poto Courtesy of the City of Austin, Texas)

## Conditions Where Practice Applies

Austin Sand Filters Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. Unlike D.C. and Delaware Sand Filters, when full sedimentation protection is provided, Austin filters may be used in situations where a higher amount of pervious surfaces are present or where higher sediment loads from deposition of wind-blown sediments are encountered. Because of their design, they may also be used on much larger drainage sheds.

Drainage Area

Austin full sedimentation and partial sedimentation basin sand filters have been used on drainage sheds up to 30 acres, and with great economy of scale. **Table 3.12-1** illustrates the relative costs of varying sized systems in Austin in mid-1990.

**TABLE 3.12C - 1**
***Cost of Austin Sand Filtration Systems*** *(June 1990)*

| Drainage Area (Acres) | Water Quality Volume ($ft^3$) | Cost/Acre ($/acre) | Cost/$ft^3$ ($/$ft^3$) | Total Cost ($) |
|---|---|---|---|---|
| 1.0 | 1815 | 13,613*<br>19,058# | 7.50*<br>10.50# | 13,613*<br>19,058# |
| 2.0 | 3,630 | 8,440*<br>9,801# | 4.65*<br>5.40# | 16,880*<br>19,602# |
| 5.0 | 9,075 | 5,136 | 2.83 | 25,682 |
| 10.0 | 18,150 | 3,812 | 2.10 | 38,115 |
| 15.0 | 27,225 | 3,086 | 1.70 | 46,283 |
| 20.0 | 36,300 | 2,723 | 1.50 | 54,450 |
| 30.0 | 54,450 | 2.360 | 1.30 | 70,785 |

Footnotes:
* Calculated from data provided by Murfee Engineers
# Calculated from data provided by Austin Stormwater Management staff
All other values derived from combined data

While Austin has traditionally built these systems in open basins, there appears no reason why the basic designs cannot be adapted to underground vault construction where real estate values are high enough to justify their use. Austin Partial Sedimentation Sand Filters have been built in underground vaults in Alexandria on sheds of three-four acres of impervious cover. Precast segmented underground vaults are now available in very large configurations. Besides the modified precast box culvert technology illustrated under **MS 3.12A: D.C. Sand Filters**, precast arch technology has also been adapted to the construction of underground vaults. **Figure 3.12C-3** shows such a system. It appears that approximately five acres of impervious cover is the uper limit of the area that should be treated by a single underground vault system.

**FIGURE 3.12C - 3**
***Underground Vault Fabricated From Precast Bridge Arch Components***

(Photo Courtesy of BridgeTek Bridge Technologies, LLC., Fredericksburg, Virginia)

<u>Development Conditions</u>

Austin Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions when constructed in underground vaults and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

## Planning Considerations

Refer to the **Planning Considerations** for **Minimum Standard 3.12: General Intermittent Sand Filter Practices**. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration (whatever the pooling depth, there must be a minimum of five feet of clearance between the top of the filter and the top slab of the filter shell to allow filter maintenance).

*Sand filter BMPS must* ***never*** *be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

## Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of Austin Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

**1.** ***Full Sedimentation with Filtration***

In this configuration, the sedimentation basin receives the WQV and detains it for a minimum draw-down time (time required to empty the basin from a full WQV condition) of 24 hours. The effluent from the sedimentation basin is discharged into the filtration basin..

Austin conducted a literature review of sedimentation basins and slow rate filters to establish design criteria.

For filtration basins, surface area is the primary design parameter. The required surface area is a function of sand permeability, bed depth, hydraulic head and sediment loading. A filtration rate of 0.0545 gallons per minute per square foot has been selected for design criteria (10.5 feet per day or 3.4 million gallons per acre per day). This filtration rate is based on a Darcy's Law coefficient of permeability k =3.5 feet per day, an average hydraulic head (h) of three (3) feet and a sand bed depth ($d_f$) of 18 inches, and a filter drawdown time, $t_f$ of 40 hours.

Substituting these values in the basic Austin Filter Formula shown in **General Intermittent Sand Filter Practices, Minimum Standard 3.12** yields:

$A_f = I_aH/18$

where "$A_f$" is the minimum surface area of the filtration media in acres, "$I_a$" is the contributing impervious runoff area in acres and "H" is the runoff depth in feet (0.5 inch = 0.0417 feet when treating the WQV).

When treating the first 1/2-inch of runoff, this formula reduces to

$A_f = 0.0023I_a = 100\ Ft^2$ of filter per impervious acre.

This formula is obviously based on a number of simplifying assumptions. Determining the actual average depth of ponding over the filter is an extremely complex proposition considering thet the runoff is being released from the sedimentation chamber to the filter at first a rising and then a falling head and then percolating through the sand filter at first a rising and then a falling head. However, this design procedure has worked well for austin for over a decade and may be therefore be considered to be vaild.

When treating a volume greater than the WQV (as when a combined quantity detention/presettling basin is utilized) use the following formula:

$A_f = 0.0023I_a \times (TV / WQV)$

Where TV = the full retention volume of the detention basin/presettling basin.

## *2. Partial Sedimentation with Filtration*

In this configuration, the sedimentation basin or chamber holds a minimum of 20 percent of the WQV and is hydraulically connected to the filter basin with orifices or slots which allow the water level to equalize between the two chambers.

For Austin Sand Filters with partial sedimentation protection, utilize the following formula:

$$A_{fm(PS)} = \frac{545 I_a d_f}{(h + d_f)}$$

where,

$I_a$ = impervious cover on the watershed in acres
$d_f$ = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

<u>Sedimentation Basin Sizing</u>

1. ***Full Sedimentation with Filtration***

The sedimentation basin must hold the entire WQV (or larger treatment volume) and release it to the filter over 24 hours. The volume of the basin is thus set by the amount of area to be treated. For sedimentation basins, the removal of discrete particles by gravity settling is primarily a function of surface loading, "$Q_o/A_s$ ", where "$Q_o$ " is the rate of outflow from the basin and "$A_s$" is the basin surface area. Basin depth is of secondary importance as settling is inhibited only when basin depths are too shallow (particle resuspension and turbulence effects). For sedimentation, surface area is the primary design parameter for a fixed minimum draw-down time, $t_d$, of 24 hours. Removal efficiency, E, is also a function of particle size distribution. For design purposes, the particles selected for complete removal in the sedimentation basin are those which are greater than or equal in size to silt with the following characteristics: particle diameter 0.00007 foot (20 microns) and specific gravity of 2.65. These are typical values for urban runoff .

Presettling basins are usually sized using the Camp-Hazen equation (Claytor and Schueler, 1996):

$$A_S = -(Q_O / w) \times Ln(1 - E)$$

Where,

$A_S$ = Surface area ($ft^2$) of the sedimentation basin
E = Trap efficiency, which is the target removal efficiency of suspended solids (use 90%)
w = Particle settling velocity; for silt, use 0.0004 ft/sec
$Q_O$ = rate of outflow from the basin = WQV (or treatment volume) divided by the detention time (24 hours)

Substituting the values recommended above yields the simplified formula:

$$A_S = 0.066 \times WQV \quad (ft^2)$$

For 1816 $ft^3$, this yields an area of 120 $ft^2$. However, Austin recommends that the sedimentation basin be no more that 10 feet deep, which yields a surface area approximately 115% of the basin Camp-Hazen area. The Austin formula for minimum surface area is:

$$A_S = 0.0042\ I_a$$

Where $I_a$ is the contributing impervious runoff area in acres

2. **Partial Sedimentation with Filtration**

The minimum area of the sediment chamber may be computed by the formula:

$$A_S = WQV / 2h$$

Where 2h = the maximum depth of ponding over the filter and the sediment chamber.

Additional Full Sedimentation Basin Considerations

1. ***Inlet Structure***

The inlet structure design must be adequate for isolating the water quality volume from the design storm and to convey the peak flow for the design storm past the basin. The water quality volume should be discharged uniformly and at low velocity into the sedimentation basin in order to maintain near quiescent conditions which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin; thus a drop inIet structure is recommended in order to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary in order to reduce inlet velocities which exceed three (3) feet per second.

2. ***Outlet Structure***

The outlet structure conveys the water quality volume from the sedimentation basin to the filtration basin. The outlet structure shall be designed to provide for a minimum draw-down time of 24 hours. A perforated pipe or equivalent is the recommended outlet structure. The 24 hour draw-down time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe (the discharges through the perforations should not be used for draw-down time design purposes)

3. ***Basin Geometry***

The shape of the sedimentation basin and the flow regime within this basin will influence how effectively the basin volume is utilized in the sedimentation process. The length to width ratio of the basin should be 2:1 or greater. Inlet and outlet structures should be located at extreme ends of the basin in order to maximize particle settling opportunities.

Short-circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. Baffles may be used to mitigate short circuiting and/or dead storage problems. The sedimentation illustrated in **Figure 3.12C-1** (photo in **Figure 3.12-4**) illustrates the use of baffles to improve sedimentation basin performance.

4. ***Sediment Trap (Optional)***

A sediment trap is a storage area which captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume which would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume. Water collected in the sediment trap shall be conveyed to the filtration basin in order to prevent standing water conditions from occurring. All water collected in the sediment trap shall drain out within 60 hours. The invert of the drain pipe should be above the surface of the sand bed filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two (2) percent slope). Access for cleaning the sediment trap drain system is necessary.

Design Storm

The inlet design or integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. Since D.C. Sand Filters will be used only as off-line facilities in Virginia, the interior hydraulics of the filter are not as critical as when used as an on-line facility. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable thatAustin Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

Special Considerations for Underground Filter Systems

When Austin Sand Filters are placed underground, a number of special considerations pertain. The restrictive orifice or gate valve for controlling the release of water from a separate sedimentation vault should be placed in a manhole located between the sedimentation vault and the filter vault. The sedimentation vault should contain a sediment sump into which accumulated sediments may be flushed with a high pressure hose for removal by vacuum trucks. Water should enter the filter vault in a separate headbox with a permanent pool for energy absorbtion and a hydrocarbon trap like that of a D.C. Sand Filter. The filter vault should also contain a separate clearwell.

Structural Requirements

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and, certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer and the structural plans require approval by the plan approving jurisdiction.

Accessibility and Headroom for Maintenance

Both the sedimentation basin and the filter must be accessible to appropriate equipment and vacuum trucks for removing accumulated sediments and trash. The sedimentation basin must be cleaned approximately once per year, and the filter will likely need raking on that frequency to remove trash and restore permeability. When filters are placed in underground vaults, all chambers must have personnel access manholes and built-in access ladders. **A minimum headspace of 60 inches above the filter is required to allow such maintenance and repair.** A 38-inch diameter maintenance manhole with eccentric nested covers ( a 22-inch personnel access lid inside the 38-inch diameter lid) or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter. A 30-inch manhole should also be placed directly over the sediment sump in an underground sedimentation vault. Similar manholes must be positioned to provide access for a high-pressure hose to reach all points in the sediment vault.

## Construction Specifications

Sedimentation Basin Liners

Impermeable liners may be either clay, concrete or geomembrane. If geomembrane is used, suitable geotextile fabric shall be placed below and on the top of the membrane for puncture protection. Clay liners shall meet the specifications in **Table 3.12C-2**:

The clay liner shall have a minimum thickness of 12 inches.

If a geomembrane liner is used it shall have a minimum thickness of 30 mils and be ultraviolet resistant.

The geotextile fabric (for protection of geomembrane) shall meet the specifications in **Table 3.12C-3**.

**TABLE 3.12C - 2**
***Clay Liner Specifications***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| Permeability | ASTM D-2434 | Cm/Sec | $1 \times 10^{-6}$ |
| Plasticity Index of Clay | ASTM D-423 & D-424 | % | Not less than 15 |
| Liquid Limits of Clay | ASTM D-2216 | % | Not less than 30 |
| Clay Compaction | ASTM-2216 | % | 95% of Standard Proctor Density |
| Clay Particles Passing | ASTM D-422 | % | Not less than 30 |

Source: City of Austin

**TABLE 3.12C - 3**
***Geotextile Specification for Basin Liner "Sandwich"***

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| Unit Weight | | Oz./Sq.Yd. | 8 (minimum) |
| Filtration Rate | | In./Sec. | 0.08 (minimum) |
| Puncture Strength | ASTM D-751 (Modified) | Lb. | 125 (minimum) |
| Mullen Burst Strength | ASTM D-751 | Psi. | 400 (minimum) |
| Tensile Strength | ASTM D-1682 | Lb. | 300 |
| Equiv. Opening Size | U.S. Standard Sieve | No. | 80 (minimum) |

Source: City of Austin

Equivalent methods for protection of the geomembrane liner will be considered on a case by case basis. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing and abrasion.

Portland Cement Concrete

Concrete liners may be used for sedimentation chambers and for sedimentation and filtration basins. Concrete shall be at least five (5) inch thick Class A3 defined in the Virginia Department of Transportation *Road and Bridge Specifications.*

Outlet Structure for Full Sedimentation Basin

A perforated pipe or equivalent is the recommended outlet structure. The 24-hour draw-down should be achieved by installing a throttle plate or other control device at the end of the riser pipe (the discharges through the perforations should not be used for draw-down time design purposes). The perforated riser pipe should be selected from **Table 3.12-4.**

**TABLE 3.12C - 4**
***Perforated Riser Pipes***

| Riser Pipe Nominal Diameter (inches) | Vertical Spacing Between Rows (Center to Center in Inches) | Number of Perforations Per Row | Diameter of Perforations (inches) |
|---|---|---|---|
| 6 | 2.5 | 9 | 1 |
| 8 | 2.5 | 12 | 1 |
| 10 | 2.5 | 16 | 1 |

Source: City of Austin

A trash rack shall be provided for the outlet. Openings in the rack should not exceed 1/3 the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a cone of one (1) to three (3) inch diameter gravel be placed around the pipe. If a geotextile fabric wrap is not used then the gravel cone must not include any gravel small enough to enter the riser pipe perforations. **Figure 3.12C-4** illustrates these considerations.

Outlet Structure for Partial Sedimentation Basin

The outlet structure should be a berm or wall with multiple outlet ports or a gabion so as to discharge the flow evenly to the filtration basin. Rock gabions should be constructed using 6-8 inch diameter rocks. The berm/wall/gabion height should not exceed six (6) feet and high flows should be allowed to overtop the structure (weir flow). Outlet ports should not be located along the vertical center axis of the berm/wall so as to induce flow-spreading. The outflow side should incorporate features to prevent gouging of the sand media (e.g., concrete splash pad or riprap)

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand** or sand meeting the Grade A fine aggregate gradation standards of Section 202 of the VDOT ***Road and Bridge Specifications.*** The top of the sand filter must be completely level.

Geotextile Fabrics

The filter cloth layer beneath the sand shall conform to the specifications shown in **Table 3.12C-5**: The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

**FIGURE 3.12C - 4**
*Riser Pipe Detail for Full Sedimentation Basin*

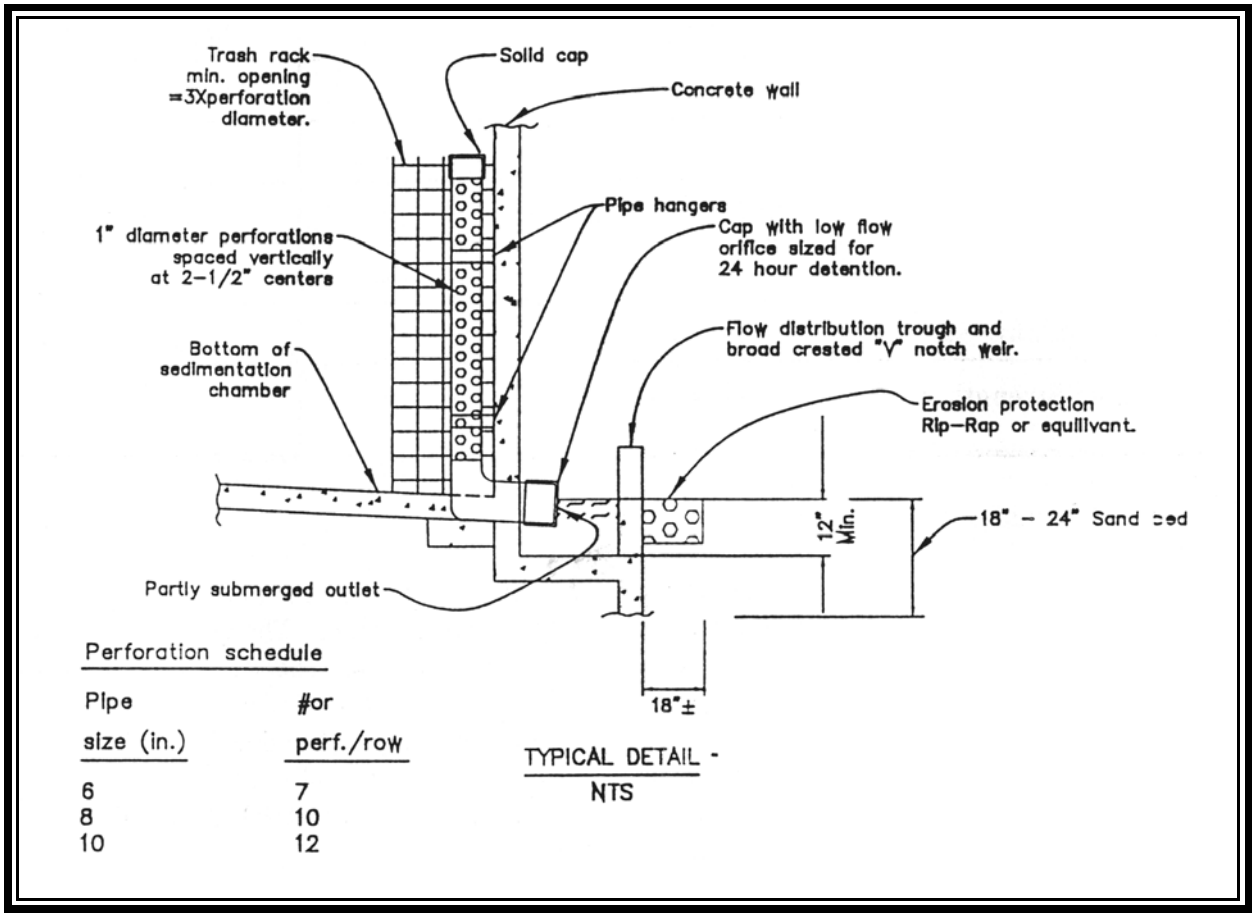



**Table 3.12C - 5**
*Specifications for Nonwoven Geotextile Fabric Beneath Sand in Austin Sand Filter*

| Property | Test Method | Unit | Specification |
|---|---|---|---|
| **Unit Weight** | -- | Oz./sq.yd. | 8.0 (min.) |
| **Filtration Rate** | -- | In/sec | 0.08 (min.) |
| **Puncture Strength** | ASTM D-751 (Modified) | Lb. | 125 (min.) |
| **Mullen Burst Strength** | ASTM D-751 | Psi | 400 (min.) |
| **Equiv. Opening Size** | U.S. Standard Sieve | No. | 80 (min.) |
| **Tensile Strength** | ASTM D-1682 | Lb. | 300 (min.) |

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes. The gravel and the sand layer are usually separated by a layer of geotextile fabric meeting the specification listedabove. However, on small underground vault partial sedimentation systems, some jurisdictions allow the substitution for an additional six-inch layer of 1/4-inch washed pea gravel in lieu of the filter fabric. In such cases, hydraulic compaction and refilling of the filter is especially important. **FIGURE 3.12C-5** shows a cross-section of a filter with the usual configuration. **FIGURE 3.12C-6** shows an underground vault filter with a six-inch pea gravel layer.

Underdrain Piping

The underdrain piping consists of 4-inch or 6-inch schedule 40 or better polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations should be 3/8 inch, and each row of perforations shall contain at least four holes for four-inch pipe and six holes for six-inch pipe. Maximum spacing between rows of perforations shall be six (6) inches. Maximum spacing between pipes shall be 10 feet.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface, e.g. the top layer of gravel.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12C-1** above.

**FIGURE 3.12C - 5**
***Austin Sand Filter Cross-Section With Filter Fabric Layer***

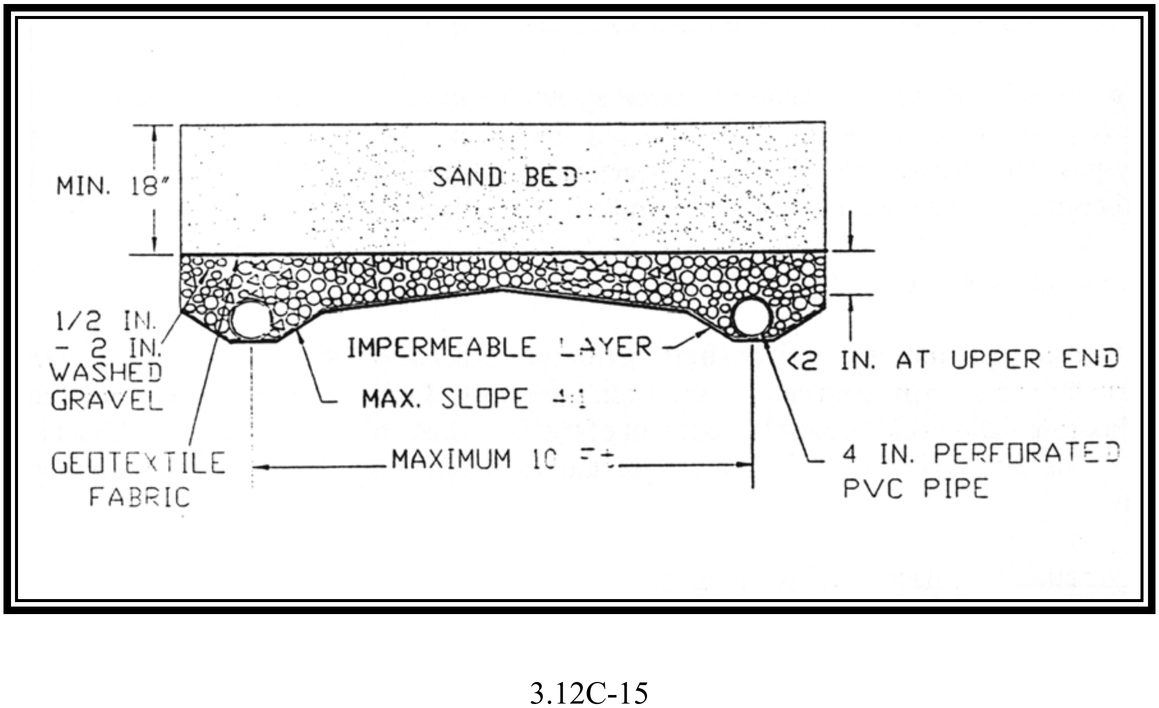
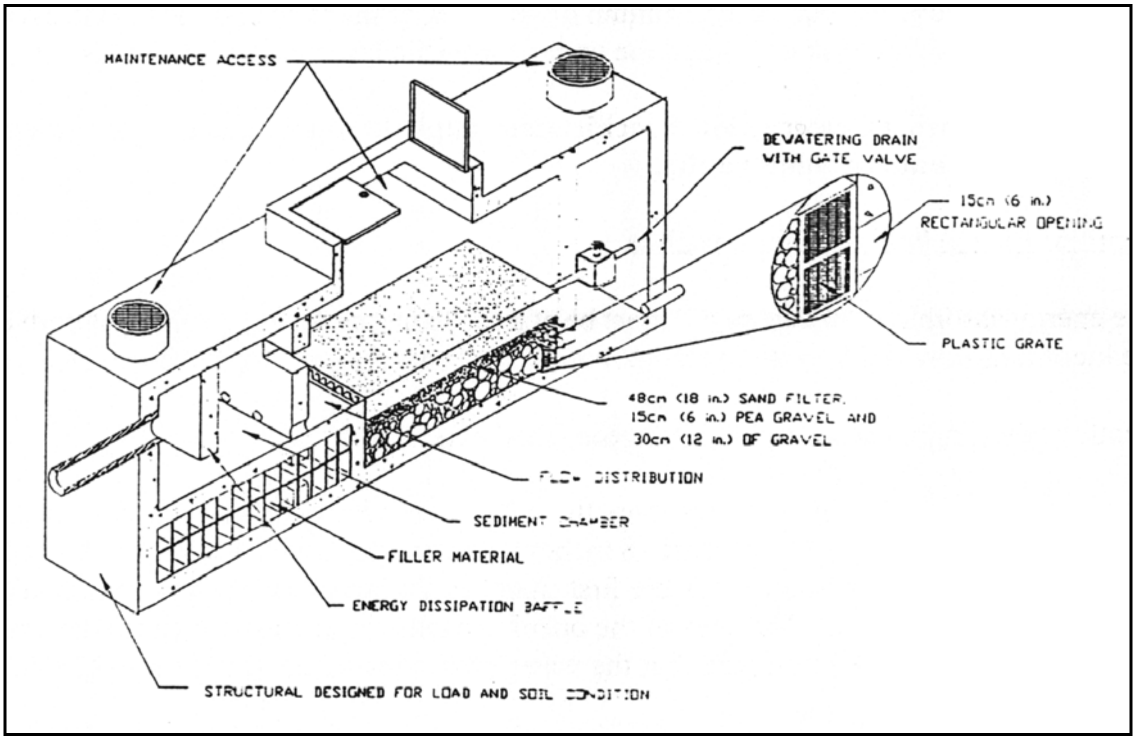


**FIGURE 3.12C - 6**
***Partial Sedimentation Vault Filter With Pea Gravel Layer***




Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

**No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation.** Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

**After completion of the filter shell but before placement of the filter layers**, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

**After placement of the collector pipes, gravel, and lower geotextile layer**, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

**Note: The following Construction Specifications apply to Austin Sand Filters which are to be constructed in underground vaults.**

Depth of Plunge Pool in Filter Headbox

The energy absorbing "plunge pool" must be at least 36 inches deep to properly absorb energy from the incoming flow and trap any hydrocarbons which pass through the sedimentation vault.

Depth of the Underwater Opening Between Chambers

To preserve an effective hydrocarbon trap, the top of the underwater opening between the headbox and the filter chamber must be at least 18 inches below the depth of the weir which divides the filter from the pool. To retain sediment in the first chamber, the bottom of the opening should be at least six inches above the floor. The area of the opening should be at least 1.5 times the cross-sectional area of the inflow pipe(s) to assure that the water level remains equal between the first and second chambers.

Total Depth of Filter Cross-Section

The total depth of the filter cross-section must match the height of the weir dividing the sedimentation pool from the filter. Otherwise, a "waterfall" effect will develop which will gouge out the front of the filter media. If a sand filter less than 24 inches is used, the gravel layer must be increased accordingly to preserve the overall filter depth.

Dewatering Drain

When the filter is placed in an underground vault, A 6-inch dewatering drain controlled by a gate valve shall be installed between the filter chamber and the clearwell chamber with its invert at the elevation of the top of the filter. The dewatering drain penetration in the chamber dividing wall shall be sealed with a flexible strip joint sealant which swells in contact with water to form a tight pressure seal.

Access Manholes

When the filter is installed in an underground vault, access to the headbox (sediment chamber) and the clearwell shall be provided through at least 22-inch manholes. Access to the filter chamber shall be provided by a rectangular door (minimum size: 4 feet by four feet) of sufficient strength to carry prospective imposed loads or by a manhole of at least 3- inch diameter with an offset concentric 22-inch lid (Neenah R-1741-D or equivalent).

Restrictive Orifice Manhole Between Vaults

The restrictive orifice or gate valve on the outlet pipe from the sedimentation vault should be placed in a manhole between the sedimentation and filter vaults with ready personnel access. **Figure 3.12C-7** illustrates this principle.

## Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Major Maintenance Requirements for Sedimentation Basins

1. Removal of silt when accumulation exceeds six (6) inches in sediment basins without sediment traps. In basins with sediment traps, removal of silt shall occur when the accumulation exceeds four (4) inches in the basins, and sediment traps shall be cleaned when full.

2. Removal of accumulated paper, trash and debris every six (6) months or as necessary.

3. Vegetation growing within the basin is not allowed to exceed 18 inches in height at any time.

4. Corrective maintenance is required any time a sedimentation basin does not drain the equivalent of the Water Quality Volume within 40 hours (i.e., no standing water is allowed).

5. Corrective maintenance is required any time the sediment trap (optional) does not drain down completely within 96 hours (i.e., no standing water allowed).

Major Maintenance Requirements for Filtration Components

1. Removal of silt when accumulation exceeds 1/2 inch. - Removal of accumulated paper, trash and debris every six (6) months or as necessary.

2. Vegetation growing within the basin is not allowed to exceed 18 inches in height.

3. Corrective maintenance is required any time draw-down does not occur within 36 hours after the sedimentation basin has emptied.

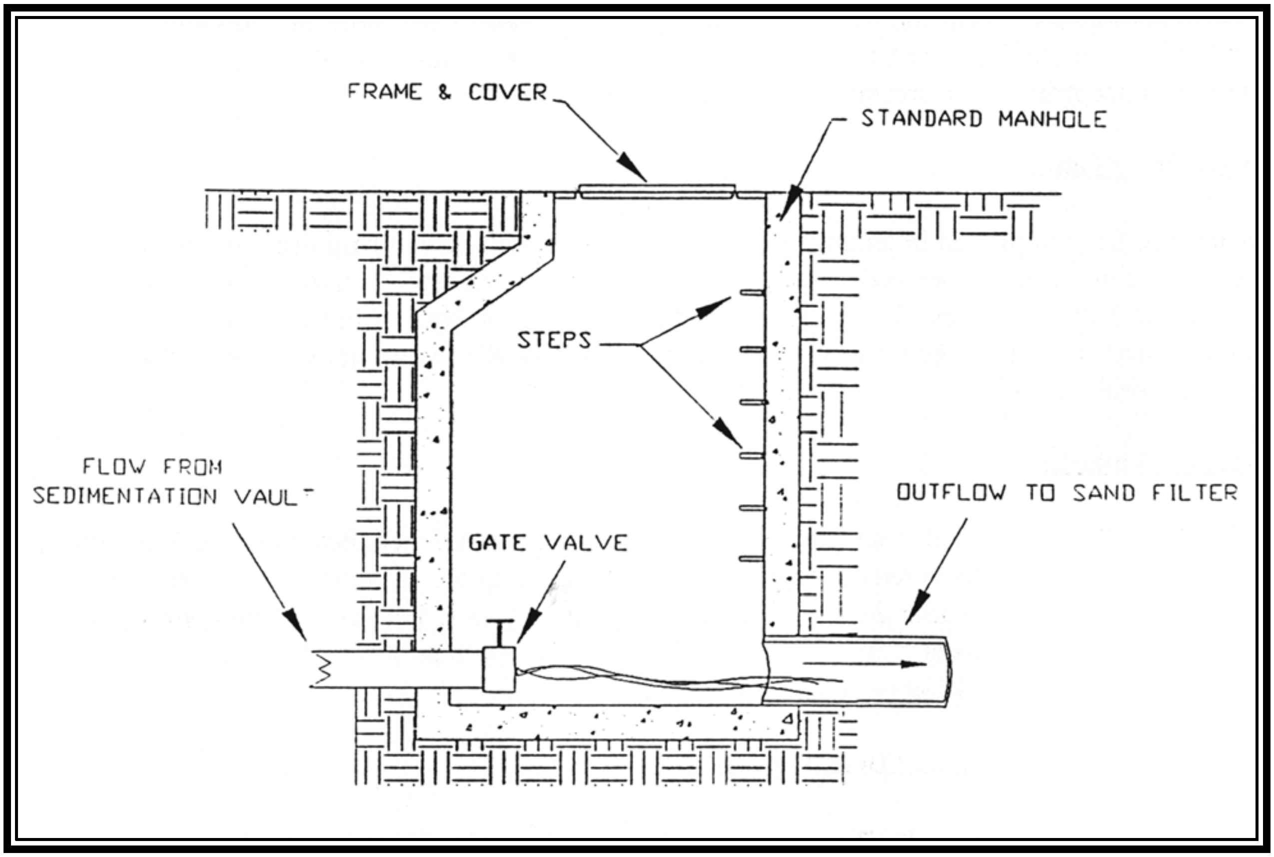
4. When an underground vault filter will no longer draw down within the required 36-hour period because of clogging with silt (approximately every 3-5 years), the upper layer of gravel and

geotechnical cloth must be replaced with new clean materials meeting the original specifications.

5. Monitoring manholes, flumes, and other facilities shall be kept clean and ready for use.

The BMP shall be inspected annually by representatives of the owner and the governing jurisdiction staff to assure continued proper functioning.

**FIGURE 3.12C - 7**
***Restrictive Orifice Access Manhole***




Sediment Chamber Pumpout

Full sedimentation chambers or basins require flushing and pumpout with a vacuum truck approximately once per year.

Concrete Shell Inspection

Concrete will deteriorate over time, especially if subjected to live loads. The concrete shell, risers, etc., must be examined during each annual inspection to identify areas that are in need of repair, and such repairs must be promptly effected.

## Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by theAustin Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used.

Standard Design Logic

Employ the following design logic to design Austin Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site ($I_a$ in acres), the water quality volume to be treated (WQV in $ft.^3 = 1816\ I_a$), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth (($d_f$) and determine the maximum achievable ponding depth over the filter (2h).

3. For Full Sedimantation Systems, size the sedimentation basin (vault) to hold the WQV with a minimum depth of 10 feet.

4. Compute the Minimum Area of the Sand Filter ($A_{fm}$)

For systems with full sediment protection, provide a dediment chamber of sufficient volume to hold the WQV. Make the depth ≤ ten feet. To compute the area of the filter, use the formula:

$$A_f = 100I_a$$

Where $I_a$ = the impervious acreage on the drainage shed.

For systems with only partial sediment protection, utilize the formula:

$$A_{fm(PS)} = \frac{545I_a d_f}{(h + d_f)}$$

$A_{fm}$ = minimum surface area of sand bed (square feet)
$I_a$ = impervious cover on the watershed in acres
$d_f$ = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

5. Select Filter Width and Compute Filter Length and Adjusted Filter Area

Considering site constraints, select the Filter Width ($W_f$). Then compute the Filter Length ($L_f$) and the Adjusted Filter Area ($A_f$)

$$L_f = A_{fm}/W_f$$

$$A_f = W_f \text{ x } L_f$$

Sizing computations are completed at this point for the full sediment protection system. The only remaining task is to assure that the filter chamber is sized to contain a minimum of 20 % of the WQV. The logic continues for the partial sedimentation system.

6. Compute the Storage Volume on Top of the Filter ($V_{Tf}$)

$$V_{Tf} = A_f \text{ x } 2h$$

7. Compute the Storage in the Filter Voids ($V_v$)
(Assume 40% voids in filter media)

$$V_v = 0.4 \text{ x } A_f \text{ x } (d_f + d_g)$$

8. Compute Flow Through Filter During Filling ($V_Q$)
(Assume 1-hour to fill per D.C. practice)

$$V_Q = \frac{kA_f(d_f + h)}{d_f} \text{ ; use } k = 2 \text{ ft./day} = 0.0833\text{/hr.}$$

9. Compute Net Volume to be Stored Awaiting Filtration ($V_{st}$)

$$V_{st} = WQV - V_{Tf} - V_v - V_Q$$

10. Compute Length of Sediment chamber ($L_{SC}$)

$$L_{SC} = \frac{V_{st}}{(2h \text{ x } W_f)}$$

11. Compute Minimum Length of Sediment Chamber ($L_s$)
(to contain 20% of WQV per Austin practice)

$$L_{sm} = \frac{0.2WQV}{(2h \text{ x } W_f)}$$

12. Set Final Length of the Sediment Chamber ($L_{SCF}$)

If $L_{SC} \geq L_s$, make $L_{SCF} = L_{SC}$

If $L_{SC} < L_{sm}$ , make $L_{SCF} = L_{sm}$

It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

## Checklists

The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

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# Chapter 3.12

Sand Filter at entrance to service station.

Sand Filter under construction. Note curb cuts for inflow to wet chamber with weir overflow into sand chamber.

# General Intermittent Sand Filters

*MINIMUM STANDARD 3.13*

# GRASSED SWALE

View BMP Images

# LIST OF ILLUSTRATIONS

# MINIMUM STANDARD 3.13

# GRASSED SWALE

## Definition

A grassed swale is a broad and shallow earthen channel vegetated with erosion resistant and flood-tolerant grasses. Check dams are strategically placed in the swale to encourage ponding behind them.

A water quality swale is a broad and shallow earthen channel vegetated with erosion resistant and flood tolerant grasses, and underlain by an engineered soil mixture.

## Purpose

The purpose of grassed swales and water quality swales is to convey stormwater runoff at a non-erosive velocity in order to enhance its water quality through infiltration, sedimentation, and filtration. Check dams are used within the swale to slow the flow rate and create small, temporary ponding areas. A water quality swale is appropriate where greater pollutant removal efficiency is desired.

Water Quality Enhancement

Grassed swalesand water quality swales remove pollution through *sedimentation*, *infiltration*, and *filtration*. Water quality swales are specifically engineered to filter stormwater through an underlying soil mixture while grasses swales are designed to slow the velocity of flow to encourage settling and filtering through the grass lining. Vegetation filters out the sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants. The flow rate becomes a critical design element, since runoff must pass through the vegetation slowly for pollutant removal to occur. Monitoring of grassed swales has indicated low to moderate removal of soluble pollutants (phosphorous and nitrogen) and moderate to high removal of particulate pollutants.

Flood Control

Grassed swales and water quality swales will usually provide some peak attenuation depending on the storage volume created by the check dams. However, flood control should be considered a secondary function of grassed swales since the required storage volume for flood control is usually more than they can provide.

**FIGURE 3.13 - 1**
***Typical Grassed Swale Configuration***

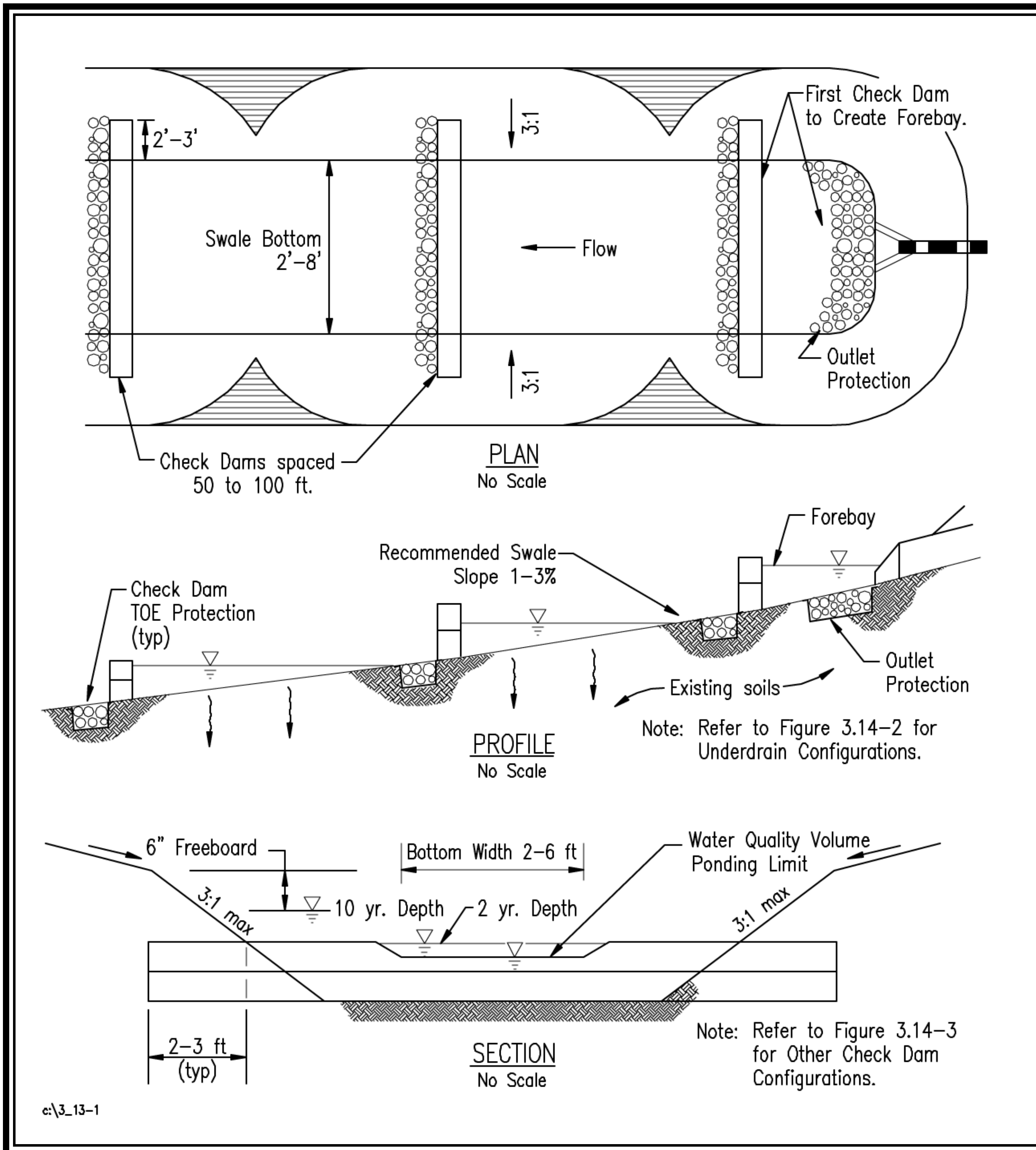


**FIGURE 3.13 - 2**

***Typical Water Quality Swale Configuration***

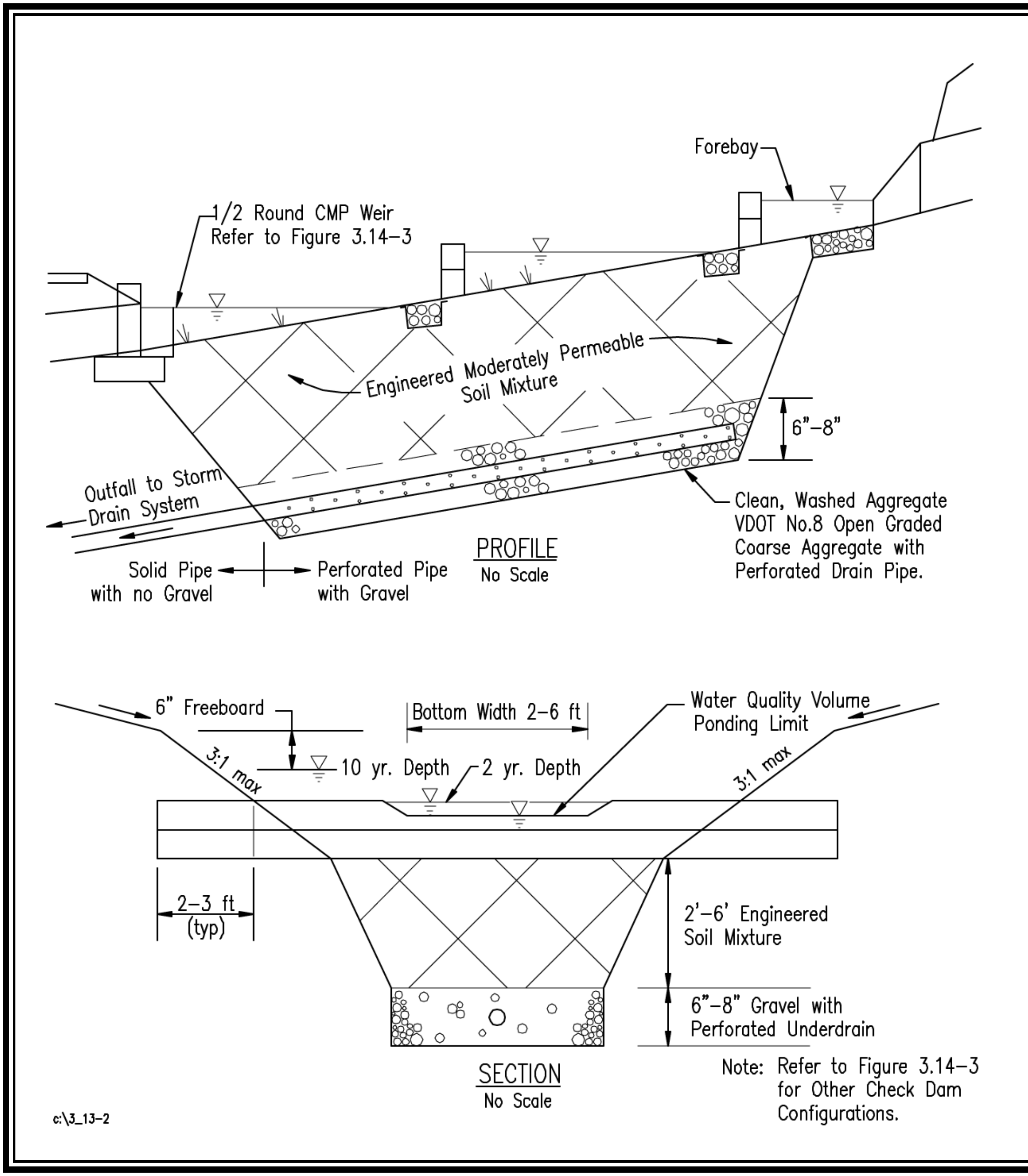


**TABLE 3.13 - 1**
***Pollutant Removal Efficiency for Grassed Swales***

| Water Quality BMP | Target Phosphorus Removal Efficiency | Impervious Cover |
|---|---|---|
| Grassed Swale | 15% | 16 - 21% |
| Water Quality Swale | 35% | 16 - 37% |

Channel Erosion Control

Grassed swales and water quality swales may also provide some benefits relative to channel erosion by reducing the peak rate of discharge from a drainage area. However, the holding capacity of a grassed swale designed for water quality purposes is limited.

## Condition Where Practice Applies

Drainage Area

Grassed swales and water quality swales engineered for enhancing water quality cannot effectively convey large flows. Therefore, their contributing drainage areas must be kept small. The dimensions (length, width, and overall geometry) and slope of the swale, and its ability to convey the 10-year storm at a non-erosive velocity will set the size of the contributing drainage area.

Development Conditions

Grassed swales are commonly used instead of curb and gutter drainage systems in low- to moderate-density (16 to 21% impervious) single-family residential developments. Since grassed swales do not function well with high volumes or velocities of stormwater, they have limited application in highly urbanized or other highly impervious areas. However, swales may be appropriate for use in these areas if they are constructed in series or as pretreatment facilities for other BMPs.

Grassed swales are usually located within the right-of-way when used to receive runoff from subdivision or rural roadways. They may also be installed within drainage easements along the side or rear of residential lots. Grassed swales can be strategically located within the landscape to intercept runoff from small impervious surfaces (small parking lots, rooftops, etc.) as a component of a subdivision-wide or development-wide BMP strategy.

Water quality swales are appropriate for the same development conditions as those listed for grassed swales with the addition of higher densities of development (16 - 37% impervious) due to the increased pollutant removal capability.

## Planning Considerations

**Figure 3.13-1** pesents a grassed swale designed to hold small pockets of water behind each check dam. The water slowly drains through small openings in the chack dam and/or infiltrates into the ground. Slow channel velocities allow the vegetation to filter out sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants.

**Figure 3.13-2** presents a water quality swale with an engineered soils media directly under the swale, with an underdrain. This design may be used in areas where the soils are not conducive to infiltration, or in developments where the swale is constructed beside a roadway using fill or compacted soils.

<u>Site Conditions</u>

The following items should be considered when selecting a grassed swale as a water quality BMP:

1. **Soils –** Grassed swales can be used with soils having moderate infiltration rates of 0.27 inches per hour (silt loam) or greater. Besides permeability, soils should support a good stand of vegetative cover with minimal fertilization.

   Water quality swales can be used in areas of unsuitable soil conditions for infiltration since the engineered soil mixture and underdrain system is used in place of the insitu soils.

2. **Topography –** The topography of the site should be relatively flat so that the swale can be constructed with a slope and cross-section that maintains low velocities and creates adequate storage behind the check dams.

3. **Depth to water table –** A shallow or seasonally-high groundwater table will inhibit the opportunity for infiltration. Therefore, the bottom of the swale should be at least 2 feet above the water table.

<u>Sediment Control</u>

Grassed swales may be used for conveyance of stormwater runoff during the construction phase of development. However, the swales should be maintained as required by the Virginia Erosion and Sediment Control Regulations and local program requirements. Before final stabilization, sediment must be removed from the swales and the soil surface prepared for final stabilization. Tilling of the swale bottom may be needed to open the surface pores and re-establish the soil's permeability.

Water quality swales should be constructed after a majority of the drainage area has been stabilized.

(Refer to **Min. Std. 3.11: Bioretention Facilities**).
This section presents minimum criteria and recommendations for the design of grassed swales used to enhance water quality. It is the designer's responsibility to decide which criteria are applicable to the particular swale being designed and to decide if any additional design elements are required. The designer must also provide for the long-term functioning of the facility by choosing appropriate structural materials.

## Design Criteria

The design of a water quality grassed swale includes calculations for traditional swale parameters (flow rate, maximum permissible velocities, etc.) along with storage volume calculations for the water quality volume.

Hydrology

The hydrology of a grassed swale's contributing drainage area should be developed per **Chapter 4, Hydrologic Methods**.

Swale Geometry

A grassed swale should have a trapezoidal cross-section to spread flows across its flat bottom. Triangular or parabolic shaped sections will concentrate the runoff and should be avoided. The side slopes of the swale should be no steeper than 3H:1V to simplify maintenance and to help prevent erosion.

Bottom Width

The bottom width of the swale should be 2 feet minimum and 6 feet maximum in order to maintain sheet flow across the bottom and to avoid concentration of low flows. The actual design width of the swale is determined by the maximum desirable flow depth, as discussed below.

Flow Depth

The flow depth for a water quality grassed swale should be approximately the same as the height of the grass. An average grass height for most conditions is 4 inches. Therefore, the maximum flow depth for the water quality volume should be 4 inches (Center for Watershed Protection, 1996).

Flow Velocity

The maximum velocity of the water quality volume through the grassed swale should be no greater than 1.5 feet per second. The maximum design velocity of the larger storms should be kept low enough so as to avoid resuspension of deposited sediments. The 2-year storm recommended maximum design velocity is 4 feet per second and the 10-year storm recommended maximum design velocity is 7 feet per second.

Longitudinal Slope

The slope of the grassed swale should be as flat as possible, while maintaining positive drainage and uniform flow. The minimum constructable slope is between 0.75 and 1.0%. The maximum slope depends upon what is needed to maintain the desired flow velocities and to provide adequate storage for the water quality volume, while avoiding excessively deep water at the downstream end. Generally, a slope of between 1 and 3% is recommended. The slope should never exceed 5%.

Swale length

Swale length is dependent on the swale's geometry and the ability to provide the required storage for the water quality volume.

Swale Capacity

The capacity of the grassed swale is a combined function of the flow volume (the water quality volume) and the physical properties of the swale such as longitudinal slope and bottom width. By using the Manning equation or channel flow nomographs, the depth of flow and velocity for any given set of values can be obtained. The Manning's '*n*' value, or roughness coefficient, varies with the depth of flow and vegetative cover. An '*n*' value of 0.15 is appropriate for flow depths of up to 4 inches (equal to the grass height). The *n* value decreases to a minimum of 0.03 for grass swales at a depth of approximately 12 inches.

A grassed swale should have the capacity to convey the peak flows from the 10-year design storm without exceeding the maximum permissible velocities. (Note that a maximum velocity is specified for the 2-year and 10-year design storms to avoid resuspension of deposited sediments and other pollutants and to prevent scour of the channel bottom and side slopes.) The swale should pass the 10-year flow over the top of the check dams with 6 inches, minimum, of freeboard. As an alternative, a bypass structure may be engineered to divert flows from the larger storm events (runoff greater than the water quality volume) around the grassed swale. However, when the additional area and associated costs for a bypass structure and conveyance system are considered, it may be more economical to simply increase the bottom width of the grassed swale. It should then be designed to carry runoff from the 10-year frequency design storm at the required permissible velocity.

The longitudinal slope and the bottom width may be adjusted to achieve the maximum allowable velocity according to the Manning equation:

$$Q = \left[\frac{1.49}{n}\, r^{2/3}\, s^{1/2}\right] A$$

**Equation 3.13-1**
Manning Equation

Where: $Q$ = peak flow rate, cfs
$n$ = Manning's roughness coefficient
$r$ = hydraulic radius, ft. = A / wp
$s$ = longitudinal slope of the channel
$A$ = cross-sectional area of the channel, $ft^2$

The portion of the equation within the brackets represents the velocity of flow. **Equation 3.13-1** can be rewritten as:

$$Q = VA$$

**Equation 3.13-2**
**Continuity Equation**

Where: $Q$ = peak flow rate, cfs
$V$ = flow velocity, ft/s = $\frac{1.49}{n}\, r^{2/3}\, s^{1/2}$
$A$ = *cross-sectional area of the channel,* $ft^2$.

Additional guidance on the use of the Manning equation for the design of grassed swales is provided in the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition.

Water Quality Volume

If a grassed swale is used as a conveyance channel, its purpose is to transport stormwater to the discharge point. However, the purpose of a water quality grassed swale is to slow the water as much as possible to encourage pollutant removal.

The use of check dams will create segments of the swale which will be inundated for a period of time. The required total storage volume behind the check dams is equal to the water quality volume for the contributing drainage area to that point. However, the maximum ponding depth behind the check dams should not exceed 18 inches. To insure that this practice does not create nuisance conditions, an analysis of the subsoil should be conducted to verify its permeability.

Underlying Soil Bed - Water Quality Swales

An underlying engineered soil bed and underdrain system may be utilized in areas where the soils are not permeable and the swale would remain full of water for extended periods of time (creating nuisance conditions). This soil bed should consist of a moderately permeable soil material with a high level of organic matter: 50% sand, 20% leaf mulch, 30% top soil. The soil bed should be 30 inches deep and should be accompanied by a perforated pipe and gravel underdrain system.

In residential developments with marginal soils, it may be appropriate to provide a soil bed and underdrain system in all grassed swales to avoid possible safety and nuisance concerns.

Check Dams

The use of check dams in a grassed swale should be per the following criteria:

1. **Height –** A maximum height of 18 inches is recommended, and the dam height should not exceed one-half the height of the swale bank.

2. **Spacing –** Spacing should be such that the slope of the swale and the height of the check dams combine to provide the required water quality volume behind the dams.

3. **Abutments –** Check dams should be anchored into the swale wall a minimum of 2 to 3 feet on each side.

4. **Toe Protection –** The check dam toe should be protected with riprap placed over a suitable geotextile fabric. The size ($D_{50}$) of the riprap should be based on the design flow in the swale. Class A1 Riprap is recommended.

5. **Overflow –** A notch should be placed in the top of the check dam to allow the 2-year peak discharge to pass without coming into contact with the check dam abutments, or the abutments may be protected with a non-erodible material. Six inches of freeboard should be provided between the 10-year overflow and the top of the swale.

6. **Riprap check dams –** Rip rap check dams should consist of a VDOT No. 1 Open-graded Coarse Aggregate core keyed into the ground a minimum of 6 inches, with a Class A1 riprap shell.

7. **Filter fabric –** Filter fabric is required under riprap and gabion check dams.

8. **Driveway culvert weirs –** Where a driveway culvert is encountered, a ½ round corrugated metal pipe weir bolted to the concrete driveway headwall may be utilized as a check dam, or a timber check dam placed at least one foot upstream of the culvert opening.

Outlets

Discharges from grassed swales must be conveyed at non-erosive velocities to either a stream or a stabilized channel to prevent scour at the outlet of the swale. Refer to VESCH, 1992 edition for design procedures and specifications regarding outlet stabilization.

Inflow Points

Swale inflow points should be protected with erosion controls as needed (e.g., riprap, flow spreaders, energy dissipators, sediment forebays, etc.).

Vegetation

A dense cover of water-tolerant, erosion-resistant grass or other vegetation must be established. Grasses used in swales should have the following characteristics:

- a deep root system to resist scouring,
- a high stem density, with well-branched top growth,
- tolerance to flooding,
- resistance to being flattened by runoff, and
- an ability to recover growth following inundation.

Recommended grasses include, but are not limited to, the following: Kentucky-31 tall fescue, reed canary grass, redtop, and rough-stalked blue grass. Note that these grasses can be mixed.

The selection of an appropriate vegetative lining for a grassed swale is based on several factors including climate, soils, and topography. For additional information, refer to STD. & SPEC. 3.32: Permanent Seeding in VESCH, 1992 edition.

Erosion control matting should be used to stabilize the soil before seed germination. This protects the swale from erosion during the germination process. In most cases, the use of sod is warranted to provide immediate stabilization on the swale bottom and/or side slopes. Refer to STD. & SPEC. 3.33: Sodding in VESCH, 1992 edition for additional information.

## Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U. S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the SCS Engineering Field Manual. Specifications for the work should conform to the methods and procedures specified for earthwork, concrete, reinforcing steel, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

### Sequence of Construction

The construction of grassed swales should be coordinated with the overall project construction schedule. The swale may be excavated during the rough grading phase of the project to permit use of the excavated material as fill in earthwork areas. Otherwise, grassed swales should not be constructed or placed into service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas may load the newly formed swale with a large volume of fine sediment. This could seriously impair the swale's natural infiltration ability.

The specifications for construction of a grassed swale should state the following:

- the earliest point in progress when storm drainage may be directed to the swale, and
- the means by which this delay in use will be accomplished.

Due to the wide variety of conditions encountered among projects, each project should be evaluated separately evaluated to decide how long to delay use of the swale.

### Excavation

Initially, the swale should be excavated to within one foot of its final elevation. Excavation to the finished grade should be deferred until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. When final grading is completed, the swale bottom should be tilled with rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

### Vegetation

Establishing dense vegetative cover on the swale side slopes and floor is required. This cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates.

Selection of suitable vegetative materials and application of required fertilizer and mulch should be per VESCH, 1992 edition.

Materials

1. **Check dams** – Check dams shall be constructed of a non-erosive material such as wood, gabions, riprap, or concrete. All check dams shall be underlaid by filter fabric per Std. & Spec 3.19: Rip Rap of VESCH, 1992 edition.

   a. *Wood* - pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.

   b. *Gabions* - hexagonal triple twist mesh with PVC coated galvanized steel wire. The maximum linear dimension of the mesh opening shall not exceed 4.5 inches. The area of the mesh opening shall not exceed 10 square inches.

   Stone or riprap for gabions shall be sized according to **Table 3.13-2**. It shall consist of field stone or rough unhewn quarry stone. The stone shall be hard and angular and of a quality that will not disintegrate with exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5.

   Recycled concrete may be used if it has a density of at least 150 pounds per cubic foot and does not have any exposed steel or reinforcing bars.

   c. *Riprap* - all riprap shall conform with VESCH Std. & Spec 3.19: Riprap, and VDOT Standards for open graded course aggregate.

   d. *Concrete* - All concrete shall conform with VDOT or SCS specifications.

2. **Underlying soil medium** – The underlying soils should consist of the following:

   a. *Soil* - USDA *ML*, *SM*, or *SC*.

   b. *Sand* - ASTM C-33 fine aggregate concrete sand; VDOT fine aggreagate, grading A or B.

3. **Pea Gravel** – Pea gravel should consist of washed ASTM M-43; VDOT No. 8 Open-graded Course Aggregate.

4. **Underdrain** – An underdrain system below the swale bottom shall consist of the following:

   a. *Gravel* - AASHTO #7, ASTM M-43, VDOT No. 3 Open-graded Course Aggregate.

   b. *PVC Pipe* - AASHTO M-278, 4-inch rigid schedule 40, perforations of 3/8-inch diameter at 6-inch centers, 4 holes per row.

   c. *Filter fabric* - shall be per specifications found in VESCH, 1992 edition.

**TABLE 3.13 - 2**
***Stone or Riprap Sizes for Gabion Baskets***

| Basket Thickness | | Stone Size *(in.)* |
|---|---|---|
| ***(in.)*** | ***(mm.)*** | |
| 6 | 150 | 3 - 5 |
| 9 | 225 | 4 - 7 |
| 12 | 300 | 4 - 7 |
| 18 | 460 | 4 - 7 |
| 36 | 910 | 4 - 12 |

## Maintenance and Inspection Guidelines

Maintenance of grassed swales includes upkeep of the vegetative cover and preservation of the swale's hydraulic properties. Individual land owners can usually carry out the suggested maintenance procedures for the swale or the portion of the swale on their property. To ensure continued long term maintenance, all affected landowners should be made aware of their maintenance responsibilities, and maintenance agreements should be included in land titles.

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific swales may require other measures not discussed here. It is the engineer's responsibility for determining if any additional items are necessary.

Vegetation

A dense and vigorous grass cover should be maintained in a grassed swale. This will be simplified if the proper grass type is selected in the design. Periodic mowing is required to keep the swale operating properly. Grass should never be cut to a height less than 3 inches. Ideally, a grass stand of 6 inches is most effective. Stabilization and reseeding of bare spots should be performed, as needed.

Check Dams

Properly constructed check dams should require very little maintenance since they are made of non-erodible materials. Periodic removal of sediment accumulated behind the check dams should be performed, as needed.

Debris and Litter Removal

The accumulation of debris (including trash, grass clippings, etc.) in the swale can alter the hydraulics of the design and lead to additional maintenance costs. Debris can also alter the flow path along the swale bottom causing low flows to concentrate and result in erosion of the swale bottom. As with any BMP, frequent inspections by the land owner will help prevent small problems from becoming larger.

Sediment Removal

The sediment that accumulates within the swale should be manually removed and the vegetation reestablished. If accumulated sediment has clogged the surface pores of the swale, reducing or eliminating the infiltration capacity, then the surface should be tilled and restabilized. Drilling or punching small holes into the surface layer can be used instead of tilling, if desired.

**FIGURE 3.13 - 3**
***Typical Check Dam Configurations***

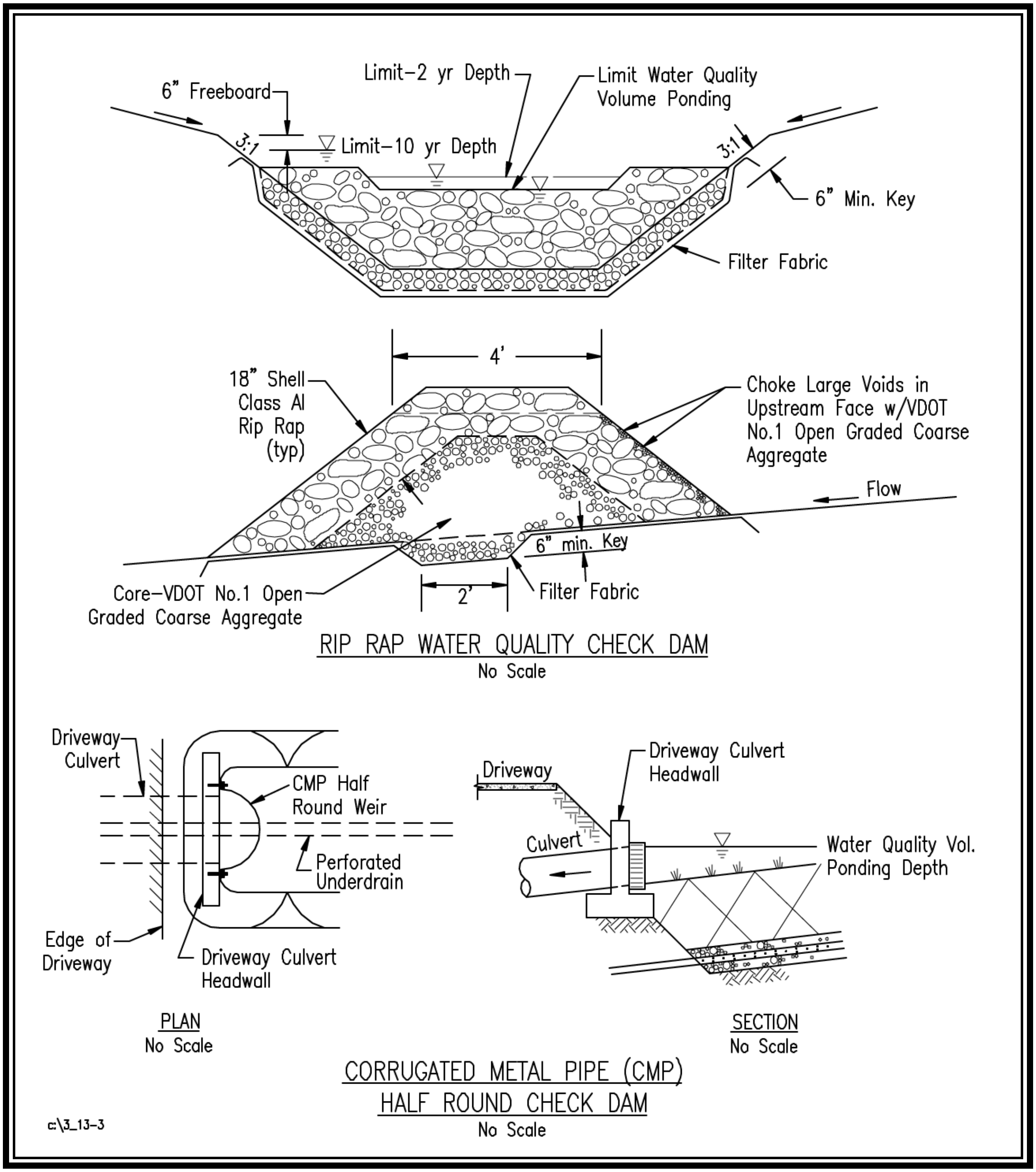
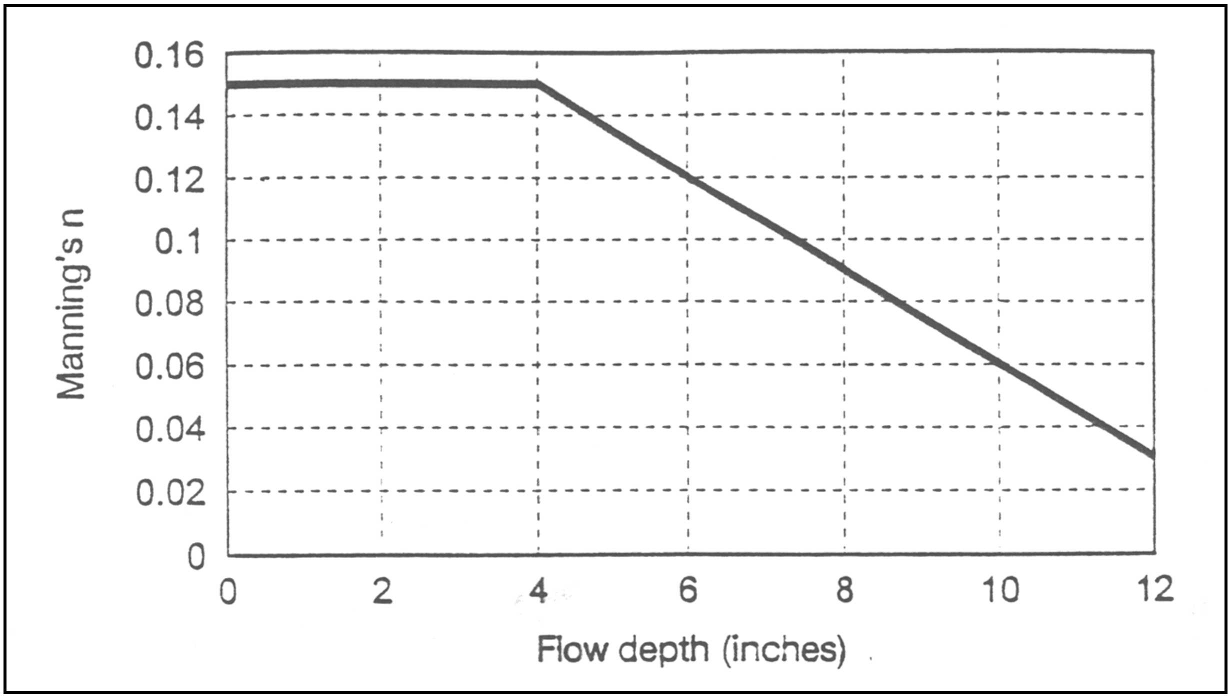


**FIGURE 3.13 - 4**
***Manning's 'n' Values for Varying Depths of Flow***



## Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of a *water quality grassed swale*.

1. Determine if the anticipated development conditions and drainage area are appropriate for a water quality grassed swale BMP.

2. Determine if the soils (permeability, bedrock, Karst, etc.) and topographic conditions (slopes, existing utilities, environmental restrictions) are appropriate for a grassed swale BMP.

3. Determine any additional stormwater management requirements (channel erosion, flooding) for the project.

4. Locate the grassed swale BMP(s) on the site.

5. Determine the hydrology and calculate the 2-year and 10-year peak discharges (**Chapter 4, Hydrologic Methods**), and the water quality volume for the contributing drainage area.

6. Approximate the geometry of the grassed swale and evaluate water quality parameters: water quality depth of flow (recommended maximum of 4 inches), and storage volume behind check dams (water quality volume). Adjust swale geometry and re-evaluate as needed.

7. Evaluate the grassed swale geometry for the the 2-year design storm peak discharge velocity (4 feet per second), and capacity (check dam overflow), and the 10-year design storm peak discharge velocity (7 feet per second) and capacity (6 inches of freeboard). (**Chapter 5, Engineering Calculations**). Adjust swale geometry and re-evaluate as needed.

8. Establish specifications for appropriate permenant vegetation on the bottom and side slopes of the grassed swale.

9. Establish specifications for sediment control.

10. Establish construction sequence and construction specifications.

11. Establish maintenance and inspection requirements.

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Grass Swale. Note stone check dam in front of inlet creates shallow ponding area to encourage infiltration and settling.

Grass Swale through residential area. Note flat slope to encourage infiltration – ponding water gone within hours of runoff producing event.

# Grassed Swale

Chapter 3.13

Grass Swale with Check Dams. Note significant channel storage capacity created by check dams. Notched center allows safe overflow without scour around sides.

# Grassed Swale

*MINIMUM STANDARD 3.14*

# VEGETATED FILTER STRIP

View BMP Images

# LIST OF ILLUSTRATIONS

**MINIMUM STANDARD 3.14**

# VEGETATED FILTER STRIP

## Definition

A vegetated filter strip is a densely vegetated strip of land engineered to accept runoff from upstream development as *overland sheet flow*. It may adopt any naturally vegetated form, from grassy meadow to small forest.

## Purpose

The purpose of a vegetated filter strip is to enhance the quality of stormwater runoff through filtration, sediment deposition, infiltration and absorption.

A vegetated filter strip may be used as a pretreatment BMP in conjunction with a primary BMP. This reduces the sediment and particulate pollutant load that could reaching the primary BMP, which, in turn, reduces the BMP's maintenance costs and enhances its pollutant removal capabilities.

**TABLE 3.14 - 1**
***Pollutant Removal Efficiency for Vegetated Filter Strips***

| BMP | Target Phosphorus Removal Efficiency | Impervious Cover |
|---|---|---|
| Vegetated Filter Strip | 10% | 16 - 21% |

Vegetated filter strips rely on their flat cross-slope and dense vegetation to enhance water quality. Their flat cross-slope assures that runoff remains as sheet flow while filtering through the vegetation. There is limited ponding or storage associated with these BMPs, so they are ineffective for reducing peak discharges. Vegetated filter strips may lower runoff velocities and, sometimes, runoff volume. Typically, however, the volume reduction is not adequate for controlling stream channel erosion or flooding.

## Conditions Where Practice Applies

Drainage Area

A vegetated filter strip should not receive large volumes of runoff since such flows tend to concentrate and form channels. Channels within a filter strip allow runoff to short-circuit the BMP, rendering it ineffective. Therefore, the contributing drainage area for a vegetated filter strip is based on the linear distance behind it that is maintained as sheet flow. Runoff is assumed to change from sheet flow to shallow concentrated flow after traveling 150 feet over **pervious** surfaces and 75 feet over **impervious** surfaces (Center for Watershed Protection, 1996). A level spreader may be used to convert shallow concentrated flow from larger areas back to sheet flow before it enters the filter strip. In any event, the contributing drainage area should never exceed five acres.

Development Conditions

Vegetated filter strips have historically been used and proven successful on agricultural lands, primarily due to their low runoff volumes. In urban settings, filter strips are most effective in treating runoff from isolated impervious areas such as rooftops, small parking areas, and other small impervious areas. Filter strips should not be used to control large impervious areas.

Since vegetated filter strips should not be used to treat concentrated flows, they are suitable only for low- to medium-density development (16-21% impervious), or as a pretreatment component for structural BMPs in higher density developments.

## Planning Considerations

Site Conditions

The following site conditions should be considered when selecting a vegetated filter strip as a water quality BMP:

1. **Soils –** Vegetated filter strips should be used with soils having an infiltration rate of 0.52 inches/hour; (sandy loam, loamy sand). Soils should be capable of sustaining adequate stands of vegetation with minimal fertilization.

2. **Topography –** Topography should be relatively flat to maintain sheet flow conditions. Filter strips function best on 5 percent or less (NVPDC).

3. **Depth of Water Table –** A shallow or seasonally high groundwater table will inhibit the opportunity for infiltration. Therefore, the lowest elevation in the filter strip should be at least 2 feet above the water table.

If the soil's permeability and/or depth to water table are unsuitable for infiltration, the filter strip's primary function becomes the filtering and settling of pollutants. A modified design may be provided to allow ponding of the water quality volume at the filter's downstream end. The ponding area may be created by constructing a small permeable berm using a select soil mixture. (For berm details, see the Pervious Berm section in this standard.) The maximum ponding depth behind the berm should be 1foot.

Water Quality Enhancement

Vegetated filter strips are occasionally installed as a standard feature in residential developments. To be used as a water quality BMP, however, filter strips must comply with certain design criteria. Vegetated filter strip designs should include specific construction, stabilization, and maintenance specifications. The most significant requirement is for runoff to be received as sheet flow. Certain enhancements may be necessary, such as added vegetation and grading specifications, or the use of level spreaders, to ensure that runoff enters the filter strip as sheet flow.

Sediment Control

**A natural area that is designed to serve as a vegetated filter strip should not be used for temporary sediment control**. Sediment deposition may have significant impacts on the existing vegetation. If a vegetated filter strip is proposed in a natural area marginally acceptable for use, due to topography or existing vegetation, then it may be appropriate to use the filter strip for temporary sediment control. However, when the project is completed, the sediment accumulation should be removed, the area should be regraded to create the proper design conditions (sheet flow), and the strip should be re-stabilized per the landscaping plan.

## Design Criteria

This section provides recommendations and minimum design criteria for vegetated filter strips intended to enhance water quality. It is the designer's responsibility to decide which criteria are applicable to the each facility and to decide if any additional design elements are required. The designer must also provide for the long-term functioning of the BMP.

Hydrology

The hydrology of a filter strip's contributing drainage area should be developed per **Chapter 4, Hydrologic Methods**.

Filter Strip Geometry

Compliance with the following parameters will result in optimal filter strip performance (NVPDC):

1. **Length** – The minimum length of a filter strip should be 25 feet, at a maximum slope of 2 percent. The length should increase by 4 feet for any 1 percent increase in slope. **The optimum filter strip length is 80 to 100 feet**.

2. **Width** – The width of the filter strip (perpendicular to the slope) should be equal to the width of the contributing drainage area. When this is not practical, a level spreader should be used to reduce the flow width to that of the filter strip. The level spreader's width will determine the depth of flow and runoff velocity of the stormwater as it passes over the spreader lip and into the filter strip. A wide lip will distribute the flow over a longer level section, which reduces the potential for concentrated flow across the filter.

3. Slope – The slope of the filter strip should be as flat as possible while allowing for drainage. Saturation may occur when extremely flat slopes are used.

Level Spreader

A level spreader should be provided at the upper edge of a vegetated filter strip when the width of the contributing drainage area is greater than that of the filter (see Figure **3.14-2**.) Runoff may be directed to the level spreader as sheet flow or concentrated flow. However, the design must ensure that runoff fills the spreader evenly and flows over the level lip as uniformly as possible. The level spreader should extend across the width of the filter, leaving only 10 feet open on each end.

Pervious Berm

To force ponding in a vegetated filter strip, a pervious berm may be installed. It should be constructed using a moderately permeable soil such as ASTM *ML*, *SM*, or *SC*. Soils meeting USDA sandy loam or loamy sand texture, with a minimum of 10 to 25% clay, may also be used. Additional loam should be used on the berm (± 25%) to help support vegetation. An armored overflow should be provided to allow larger storms to pass without overtopping the berm. **Maximum ponding depth behind a pervious berm is 1 foot**.

Vegetation

A filter strip should be densely vegetated with a mix of erosion resistant plant species that effectively bind the soil. Certain plant types are more suitable than others for urban stormwater control. The selection of plants should be based on their compatibility with climate conditions, soils, and topography and the their ability to tolerate urban stresses from pollutants, variable soil moisture conditions and ponding fluctuations. Virginia has three major physiographic regions that reflect changes in soils and topography: Coastal Plain, Piedmont, and Appalachian and Blue Ridge regions (see **Figure 3.14- 3**).

A filter strip should have at least two of the following vegetation types:

- *deep-rooted grasses, ground covers, or vines*
- *deciduous and evergreen shrubs*
- *under- and over-story trees*

Native plant species should be used if possible. Non-native plants may require more care to adapt to local hydrology, climate, exposure, soil and other conditions. Also, some non-native plants may become invasive, ultimately choking out the native plant population. This is especially true for non-native plants used for stabilization.

Newly constructed stormwater BMPs will be fully exposed for several years before the buffer vegetation becomes adequately established. Therefore, plants which require full shade, are susceptible to winter kill or are prone to wind damage should be avoided.

Plant materials should conform to the American Standard for Nursery Stock, current issue, as published by the American Association of Nurserymen. The botanical (scientific) name of the plant species should be according to the landscape industry standard nomenclature. All plant material specified should be suited for USDA Plant Hardiness Zones 6 or 7 (see **Figure 3.14- 4**).

## Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable to construct a vegetated filter strip. The specifications should also satisfy all requirements of the local government.

Sequence of Construction

Vegetated filter strip construction should be coordinated with the overall project construction schedule. Rough grading of the filter strip should not be initiated until adequate erosion controls are in place.

Soil Preparation

Topsoil should be 8 inches thick, minimum. If grading is necessary, the topsoil should be removed and stockpiled. If the subsoil is either highly acidic or composed of heavy clays, ground dolomite limestone should be applied at an appropriate rate based on soil and slope conditions.

Subsoil should be tilled to a depth of at least 3 inches to adequately mix in soil additives and to permit bonding of the topsoil to the subsoil. If the existing topsoil is inadequate to support a densely vegetated filter strip, then suitable material should be imported. Proper specifications for imported topsoil should include the following:

1. *The USDA textural triangle classification.*

2. *Requirements for organic matter content (not less than 1.5% by weight), pH (6 to 7.5), and soluble salt (not greater than 500 parts per million).*

3. *Placement thickness and compaction. Topsoil should be uniformly distributed and compacted, and should have a minimum compacted depth of 6 to 8 inches.*

All seeding, fertilization, and mulching should be per the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition, or as specified by a qualified agronomist.

## Maintenance/Inspection Guidelines

Vegetated filter strips require regular maintenance. Field studies indicate that these BMPs usually have short life spans because of lack of maintenance, improper location, and poor vegetative cover.

The following maintenance and inspection guidelines are **NOT** all-inclusive. Specific facilities may require other measures not discussed here. It is the designer's responsibility to decide if additional measures are necessary.

Filter strips should be inspected regularly for gully erosion, density of vegetation, damage from foot or vehicular traffic, and evidence of concentrated flows circumventing the strip. The level spreader should also be inspected to verify that it is functioning as intended.

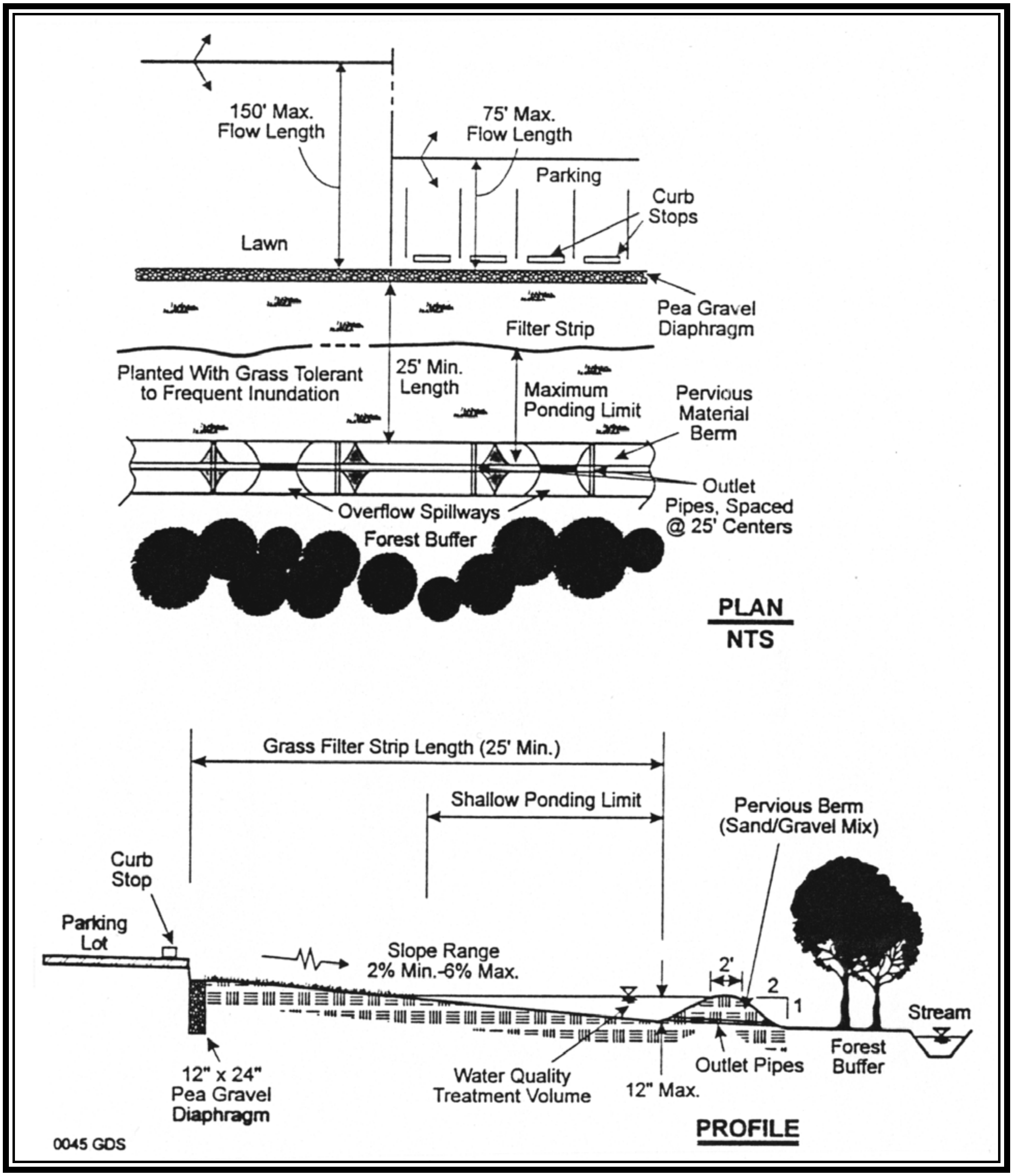
Inspections are critical during the first few years to ensure that the strip becomes adequately established. Maintenance is especially important during this time and should include watering, fertilizing, re-seeding or planting as needed.

Once a filter strip is well established and functioning properly, periodic maintenance, such as watering, fertilizing and spot repair, may still be necessary. However, fertilization efforts should be minimized. Natural selection allows certain species (usually native plants) to thrive while others decline. Excessive fertilization and watering to maintain individual plantings may prove costly, especially in abnormally dry or hot seasons. Overseeding and replanting should be limited to those species which have exhibited the ability to thrive.

To increase the functional longevity of a vegetated filter strip, the following practices are recommended:

- *Regular removal of accumulated sediment,*
- *periodic reestablishment of vegetation in eroded areas or areas covered by accumulated sediment,*
- *periodic weeding of invasive species or weeds, and*
- *periodic pruning of woody vegetation to stimulate growth.*

**FIGURE 3.14 - 1**
*Vegetated Filter Strip*




Source: Design of Stormwater Filtering Systems, Center for Watershed Protection,1996

**FIGURE 3.14 - 2**

*Level Spreader*

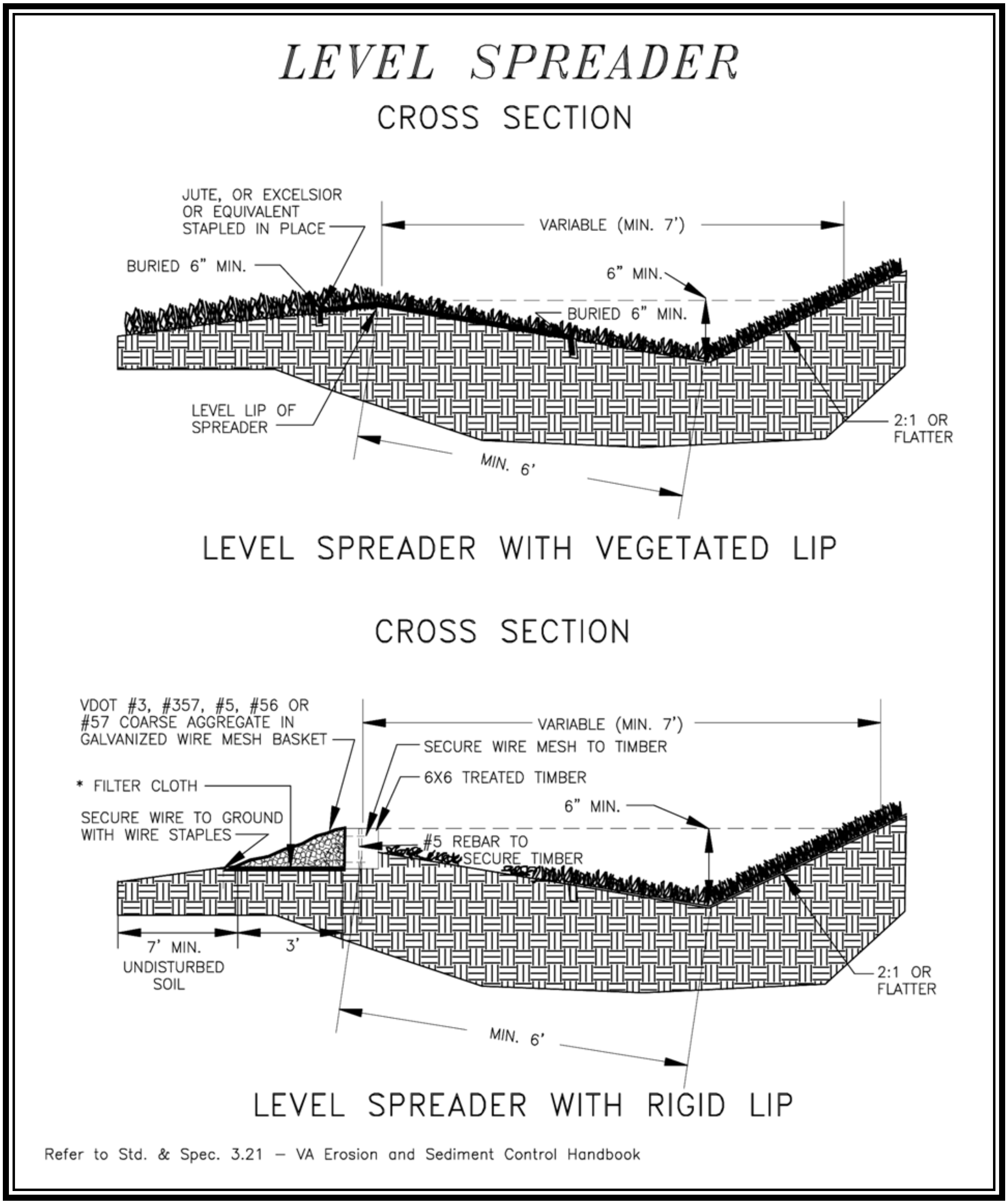


**FIGURE 3.14 - 3**
*Virginia Physiographic Regions*

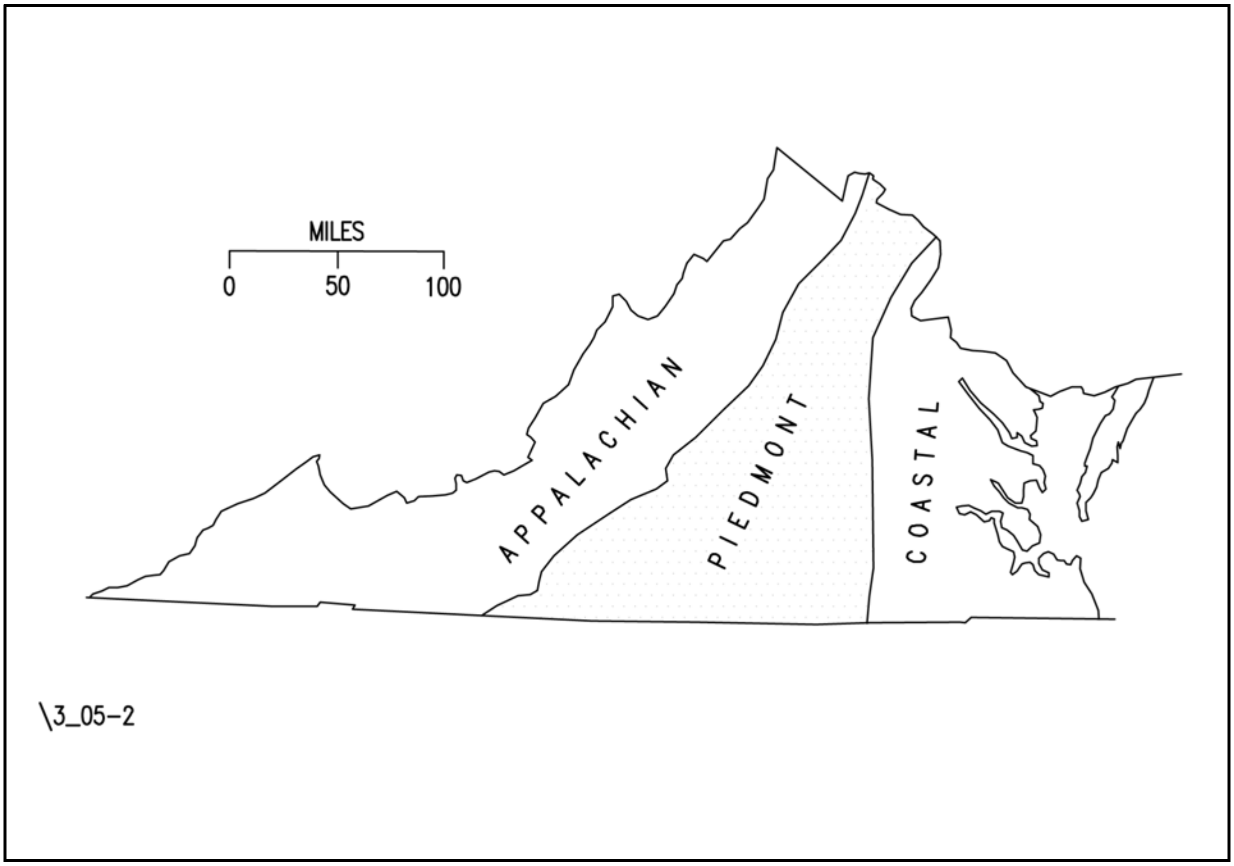
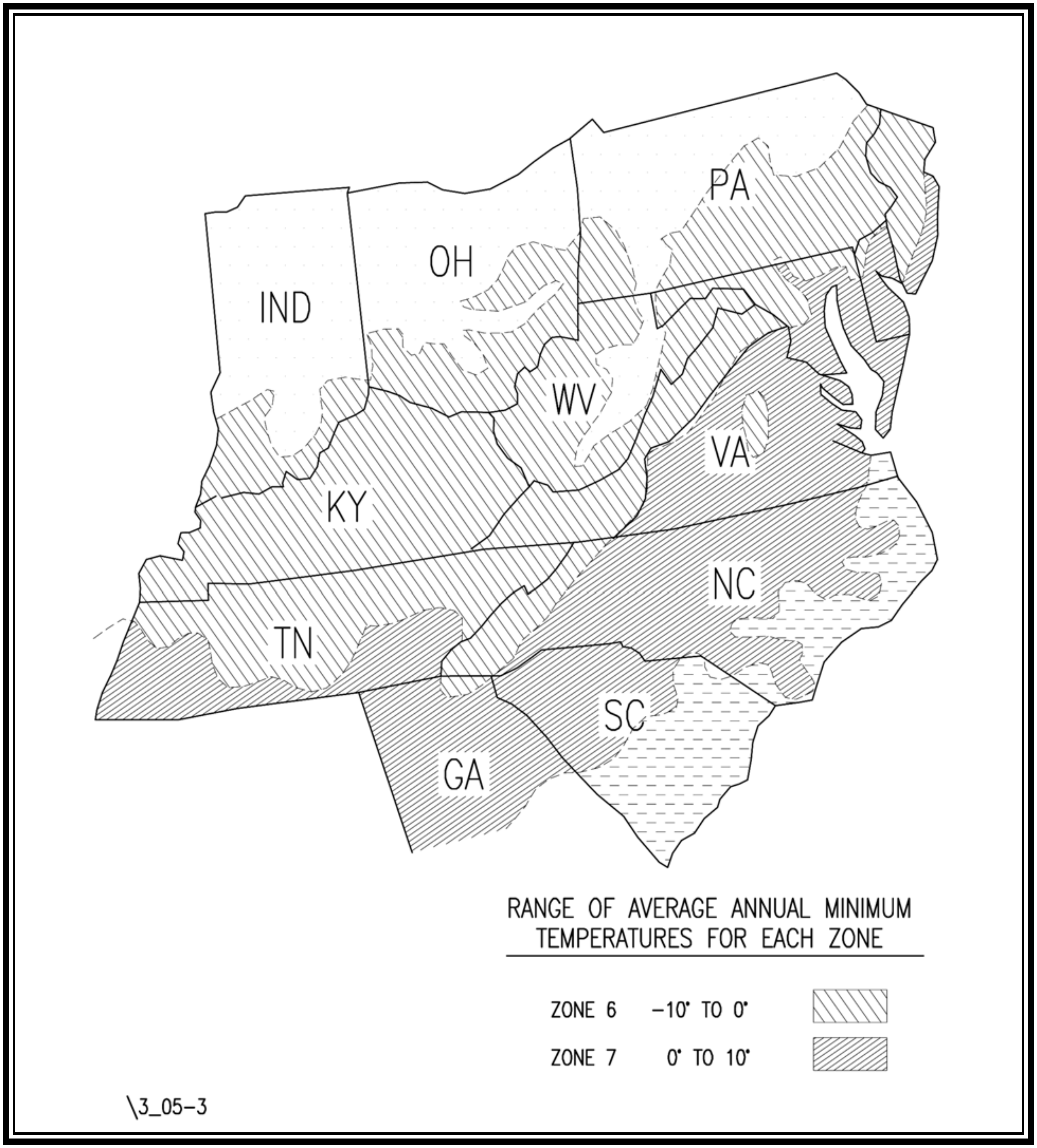


**FIGURE 3.14 - 4**
***USDA Plant Hardiness Zones***



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Vegetated Filter Strip. Note landscaped areas parallel to contours to force runoff to spread out. No evidence of channel flow short circuiting filter strip.

## *MINIMUM STANDARD 3.15*

# MANUFACTURED BMP SYSTEMS



View BMP Images

# LIST OF ILLUSTRATIONS

## MINIMUM STANDARD 3.15

# MANUFACTURED BMP SYSTEMS

The Manufactured BMP Systems presented in this standard have been presented to the Virginia Department of Conservation and Recreation (DCR) by industry manufacturers. DCR acknowledges that there may be additional Manufactured BMP Systems available at this time that are not presented in this handbook. Presentation of the following products does not preclude the use of other available systems, nor does it constitute endorsement of any one system. Additional BMP systems will be presented in Technical Bulletins as they become available.

### Definition

A Manufactured BMP system is a structural measure which is specifically designed and sized by the manufacturer to intercept stormwater runoff and prevent the transfer of pollutants downstream.

### Purpose

Manufactured BMP systems are used solely for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible. These are flow-through structures in that the design rate of flow into the structure is regulated by the inflow pipe or structure hydraulics as opposed to traditional BMPs designed to store the entire water quality volume. When the maximum design inflow is exceeded, the excess flow bypasses the structure or flows through the structure and bypasses the treatment with minimal turbulence and resuspension of previously trapped pollutants. Structures that rely on the inflow pipe to regulate the rate of flow into the treatment chamber typically cause stormwater to back up into the upstream conveyance system or associated storage facility. Depending on the type of structure and the configuration of the conveyance system, this excess flow will either bypass the treatment chamber or be attenuated and allowed to flow through the treatment chamber at the regulated rate.

Pollutant removal efficiencies presented in this standard are based upon currently available studies. Removal efficiencies are very variable, however, and highly dependant on storm size, influent pollutant concentrations, and rainfall intensity. Several monitoring studies are ongoing and many products may be modified to improve pollutant removal performance. Therefore, the removal efficiencies presented may be subject to change. As more of these products are built and additional monitoring studies track their performance over a wide range of rainfall events, the anticipated performance of these systems as water quality BMPs will become better established.

The discussion of each of the manufactured BMP systems presented in this standard includes the target pollutants for which the BMP was designed. Many of these systems were developed to remove a specific range of particulate pollutants, or total suspended solids (TSS), from stormwater runoff. Others, such as the filtering structures discussed below, were developed to capture a broad range of pollutants. The use of phosphorus as the target or "keystone" pollutant is recommended when using the *performance-based* water quality criteria to select a BMP. However, for stormwater "hot-spots", or areas from which a high concentration of urban pollutants can be expected, the primary pollutant of concern may be hydrocarbons (oil and grease), metals, or other compounds besides nutrients. Manufactured BMPs generally provide effective spill containment for material handling and transfer areas such as automobile fuel and service areas, and other urban hot-spots. Careful analysis of the proposed development project and intended uses help in selecting and appropriate BMP.

The manufactured BMP systems which have been evaluated at this time can be categorized as either:

- **Hydrodynamic Structures** - (*Stormceptor, Vortechs Stormwater Treatment System, Downstream defender, BaySaver Separation System*)

- **Filtering Structures** - (*StormFilter, StormTreat System*)

**Hydrodynamic Structures**

Hydrodynamic structures are those which rely on settling or separation of pollutants from the runoff. The hydrodynamic structures can be generally categorized as Chambered Separation Structures or Swirl Concentration Structures.

<u>Chambered Separation Structures</u> rely on settling of particles and, to a lesser degree, centrifugal forces to remove pollutants from stormwater. These structures contain an upper bypass chamber and a lower storage/separation chamber. Flow enters the structure in the upper bypass chamber and is channeled through a downpipe into the lower storage/separation, or treatment, chamber. The downpipe is configured such that when the rate of inflow into the structure exceeds its operating capacity, the flow simply "jumps" over the downpipe, bypassing the lower treatment chamber.

The outlet configuration of the downpipe forces the water to enter the lower treatment chamber in one direction, which encourages circular flow. This circular flow, as well as gravitational settling, traps the sediments and other particulate pollutants (as well as any pollutants which adsorb to the particulates) at the bottom of the chamber. The water leaves the treatment chamber through a return or riser pipe. The return or riser pipe extends below the water surface within the lower treatment chamber in order to prevent trapped floatables from exiting the structure. The hydraulic gradient of the structure prevents the inflow and the discharge from creating turbulent conditions within the lower treatment chamber. This feature helps prevent the resuspension of previously trapped particulate pollutants during high flow, or "bypass", storm events.

Swirl Separation Structures are characterized by an internal component that creates a swirling motion. This is typically accomplished by a tangential inflow location within a cylindrical chamber. The "swirl" technology is similar, if not identical to, the technology used in treating combined sewer overflows. The solids settle to the bottom and are trapped by the swirling flow path. Additional compartments or chambers act to trap oil and other floatables.

There is no bypass for larger flows prior to the treatment or swirl chamber. The larger flows simply pass through the structure untreated. However, due to the swirling motion within the structure, larger flows do not resuspend previously trapped particulates.

**Filtering Structures**

Filtering structures are characterized by a sedimentation chamber and a filtering chamber. The manufactured systems presented in this standard, the *StormFilter* and the *StormTreat System*, use very different configurations and filtering media. Both contain a primary settling chamber to remove heavy solids, floatables, oil, etc. The *StormTreat System* then directs the water through a series of screens and geotextile filters and into a containerized wetland system with soil and aquatic plants. The *StormFilter*, on the other hand, uses any one or combination of filter media cartridges. The filter media selected is typically based on the target pollutants to be removed or the desired efficiency. The number of cartridges is dependent on the project size, desired removal efficiency, and peak flow rates.

**These categories represent the general groupings of manufactured systems that have been presented to DCR to date. More systems may be added in the future as they become available.**

**TABLE 3.15-1**

***Pollutant Removal Efficiencies for Manufactured BMPs***

| Type | Target Phosphorus Removal Efficiency* |
|---|---|
| Hydrodynamic Structures (*Stormceptor, Vortechs, Downstream Defender, BaySaver*) | 15% - 20% |
| Filtering Structures (*StormFilter, StormTreat System*) | 50% |

*Pollutant removal efficiencies are subject to change pending monitoring results.

## Conditions Where Practice Applies

Drainage Area

The sizing criteria for each manufactured BMP system should be obtained from the manufacturer to insure that the latest design and sizing criteria is used. In general, the flow-through configuration and treatment limitations will force drainage areas to remain relatively small.

Development Conditions

Manufactured BMP systems are ideal for use in ultra-urban areas since they are space efficient. Most of these systems can be placed under parking lots, or simply installed as a manhole junction box or inlet structure. Since other BMPs, such as sand filters and bioretention structures, are also suited for urban development, the designer must consider the type of pollutant load anticipated from the site, as well as other site factors, such as maintenance, aesthetics, etc., and select an appropriate BMP. In general, hydrodynamic are recommended for the following:

- Pretreatment for other BMPs;
- Retrofit of existing development or Redevelopment; and
- Ultra-urban development areas.

Filtering structures are generally recommended for use in applications similar to General Intermittent Sand Filters (**Minimum Standard 3.12**) and Bioretention Filters (**Minimum Standard 3.11**).

In all cases, Manufactured BMP systems must be designed in accordance with the manufacturers specifications.

## Planning Considerations

The most significant feature of manufactured BMP systems is their small size and the ability to use them as retrofits underneath improved areas. (It should be noted that other BMPs, such as sand filters, can also be placed under improved areas.) The fact these BMPs are underground requires the designer to locate an acceptable outfall or improved drainage system for discharging runoff. The vertical elevation of the inflow and outflow pipe connections may be critical to the choice, or design, of the BMP.

Overflow

All of the manufactured BMP systems presented in this standard are flow-through structures that can be located on storm drainage systems that drain improved areas. Most manufactured systems, however, are designed to treat the first flush, or the water quality volume, of runoff. Therefore, an overflow, or bypass, is needed to divert flow that exceeds the design rate, or a storage facility is needed to store the appropriate volume of runoff for treatment. The discussion of each manufactured system will include the overflow or bypass provisions provided, or required.

## Design Criteria

The design criteria for manufactured BMP systems should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is appropriately designed and sized.

## Maintenance and Inspections

All manufactured BMP systems require regular inspection and maintenance to maximize their effectiveness. The specific maintenance requirements and schedule should be prepared by the manufacturer and signed by the owner/operator. It should be noted that the frequency of maintenance is not only dependent on the type of manufactured system chosen, but also the pollutant load from the contributing drainage area. The frequency of maintenance required may vary from after any major storm, to once a month, to up to twice a year.

A maintenance log should be required to keep track of routine inspections and maintenance. A maintenance log can also help facility owners establish the effectiveness of certain “housekeeping” practices, such as street sweeping. Failure to maintain any stormwater BMP may result in reduced efficiency, resuspension or mixing of previously trapped pollutants, or clogging of the system.

Many suppliers of manufactured BMP systems recommend service contracts to ensure that maintenance occurs on a regular basis. Lack of maintenance is widely acknowledged to be the most prevalent cause of failure of both structural and non-structural BMPs.

Another consideration with manufactured BMP systems is the possible contamination and toxicity of trapped sediments, especially in areas considered to be stormwater hot-spots. Care must be taken in the disposal of sediment that may contain accumulations of heavy metals. Sediment testing is recommended prior to sediment removal to assure proper disposal. Experience in other jurisdictions has indicated a reluctance to on the part of waste water utility operators to accept the pump-out material from these structures. Landowners are encouraged to research the disposal options as part of the planning process prior to selecting the BMP.

## MINIMUM STANDARD 3.15A

# STORMCEPTOR

### Description

*Stormceptor* is a precast, modular, vertical cylindrical tank, which is divided into an upper bypass chamber and a lower storage/separation chamber. Under normal design flow operating conditions flow enters the structure through the upper chamber and is diverted by a U-shaped weir through a downpipe and into the lower separation/holding, or treatment, chamber. The downward flow is redirected horizontally around the circular walls of the separation chamber by a tee-fitting on the downpipe outlet. This circular flow, as well as gravitational settling, traps sediments and other particulate pollutants (as well as any pollutants which adsorb to the particulates) at the bottom of the chamber.

Water exits the lower chamber through a submerged outlet riser pipe. The bottoms of the inlet downpipe and the outlet riser pipe are submerged and set at the same elevation (the elevation that provides the oil/floatable storage above the pipes, and the solids/sediment storage below the pipes). The submerged outlet riser pipe prevents trapped floatables from exiting the structure. This configuration prevents the inflow and discharge from creating turbulent flow conditions within the lower treatment chamber, thus avoiding resuspension and export of previously trapped pollutants during high flow, or “bypass,” storm events.

There are no moving parts and no external power requirements for the *Stormceptor*.

**Overflow** – During-high flow periods, stormwater floods over the diversion weir and continues through the upper bypass chamber into the downstream sewer. This rapid activity creates pressure equalization across the bypass chamber, thus decreasing the flow through the lower treatment chamber, and preventing scour and resuspension of previously trapped materials.

**Hydraulics** – The overflow of the system is controlled by the incoming velocity and the hydraulics of the diversion weir. This system will cause a slight backwater condition in the upstream conveyance system.

## Planning Considerations

*Stormceptor* is precast and comes in various sizes and is designed for all types of land uses. The system is engineered for traffic loading and can be installed as a manhole structure on an existing system (as a retrofit) or on a new system where water quality enhancement is required.

**Target Pollutants** – *Stormceptor* is designed to capture sediment, total suspended solids (TSS), trash, organic material, and floatable oil and grease. In addition, many other urban pollutants which adsorb to sediments and particulates can also be trapped by the structure.

## Design Criteria

The design criteria for the *Stormceptor* should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is appropriately designed and sized.

## Maintenance and Construction

It is generally recommended that the system be maintained (full pump-out) once per year. This frequency may have to be adjusted to a shorter interval once loading rates are determined. Regular inspections will help determine the required frequency of cleaning. More frequent inspections are appropriate where oil spills occur regularly. Maintenance is completed using a conventional vacuum truck.

**Contact:**

Mr. Vince Berg, P.E.
Stormceptor Corporation
600 Jefferson Plaza
Suite 304
Rockville, Maryland 20852
Phone: 1-800-762-4703

**FIGURE 3.15-1**
***Stormceptor - Normal Flow Conditions***

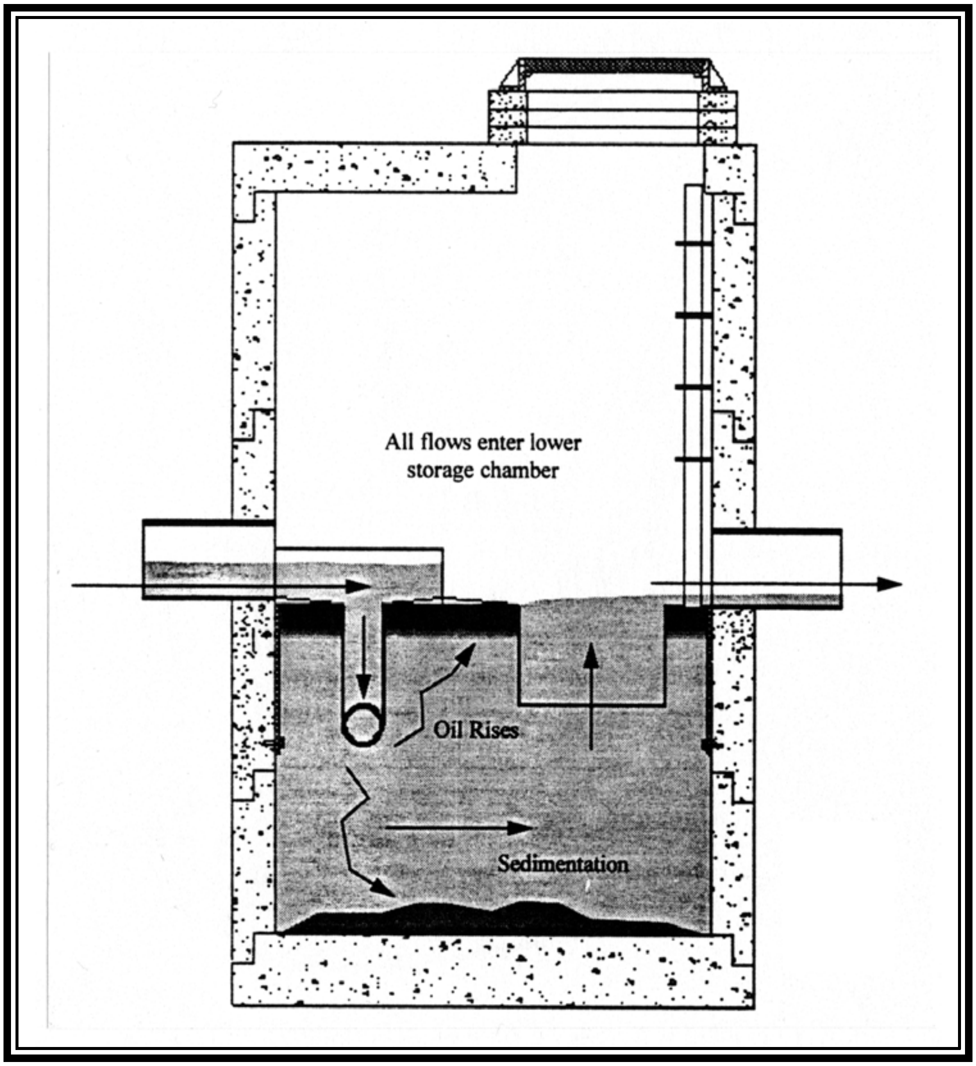
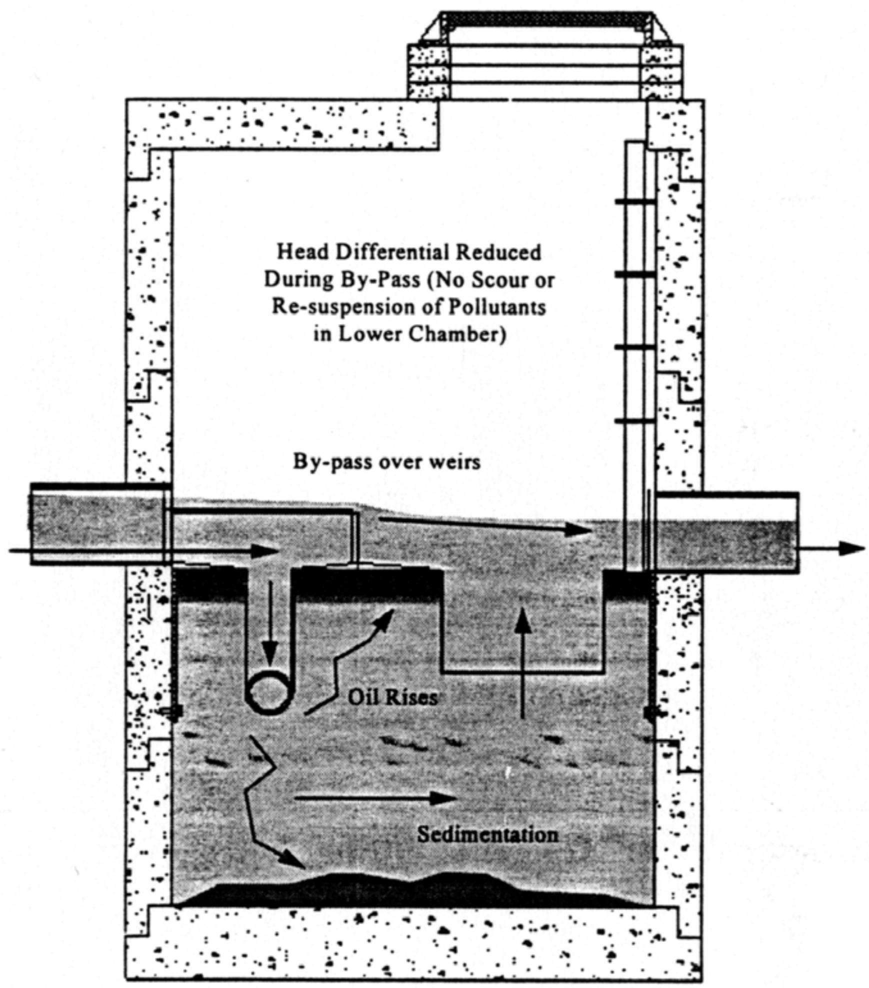


**FIGURE 3.15-2**
*Stormceptor - High Flow Conditions*



## MINIMUM STANDARD 3.15B

# VORTECHS STORMWATER TREATMENT SYSTEM

### Description

The *Vortechs Stormwater Treatment System* is a precast rectangular unit with three chambers. The first chamber is referred to as the grit chamber and consists of a 1/4-inch thick aluminum cylinder with openings to release water at a controlled rate. The flow enters this chamber at a tangent to create a swirling motion that directs settlable solids towards the center. The flow is slowly released from the swirl concentrator into the oil chamber. The oil chamber has a barrier which traps oil and grease and other floatables. The final chamber is the flow control chamber, which forces water to back up in the structure, this reducing the inflow velocities and turbulence.

There are no moving parts and no external power requirements for the *Vortechs System.*

**Overflow** - As the rate of runoff increases, the flow control chamber forces the runoff to fill the *Vortechs* structure. As this occurs, the swirling action in the grit chamber increases, keeping sediments and other material concentrated at the center of the chamber. The flow will back up to a level established by the elevation of the release openings within the overflow chamber. This provides the ability to achieve flow attenuation within the storage capacity of the upstream storm drainage system. If additional flow attenuation or quantity controls are needed, the elevation of the *Vortechs System* can be manipulated to back up water into a detention facility. Because the swirling action increases as the inflow velocity increases, resuspension of previously deposited material during high flows is eliminated.

**Hydraulics** - The hydraulics of the *Vortechs System* allow for the treatment of runoff from frequent storms as well as the flow from larger, less frequent storms. Larger storms will cause runoff to back up in the drainage system as the storage volume within the structure is above the inflow pipes.

### Planning Considerations

The *Vortechs Stormwater Treatment System* is precast and comes in various sizes and is designed for all types of land uses. The system can be engineered for traffic loading, and depending on the invert elevations can be installed on an existing pipe system (as a retrofit) or on a new system where water quality enhancement is required.

**Target Pollutants** – The *Vortechs System* is designed to capture sediment as fine as clay sized particles, and the nutrients and metals that adhere to sediments. Also targeted are floating materials, including petroleum products.

## Design Criteria

The design criteria for the *Vortechs System* should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is correctly designed and sized.

## Maintenance and Inspections

The *Vortechs System* has no ongoing maintenance requirements, although routine inspections are necessary to schedule cleaning. To insure proper performance and treatment efficiency, the system must be cleaned out when it is full. The rate at which the system accumulates contaminants is largely dependent upon site activities.

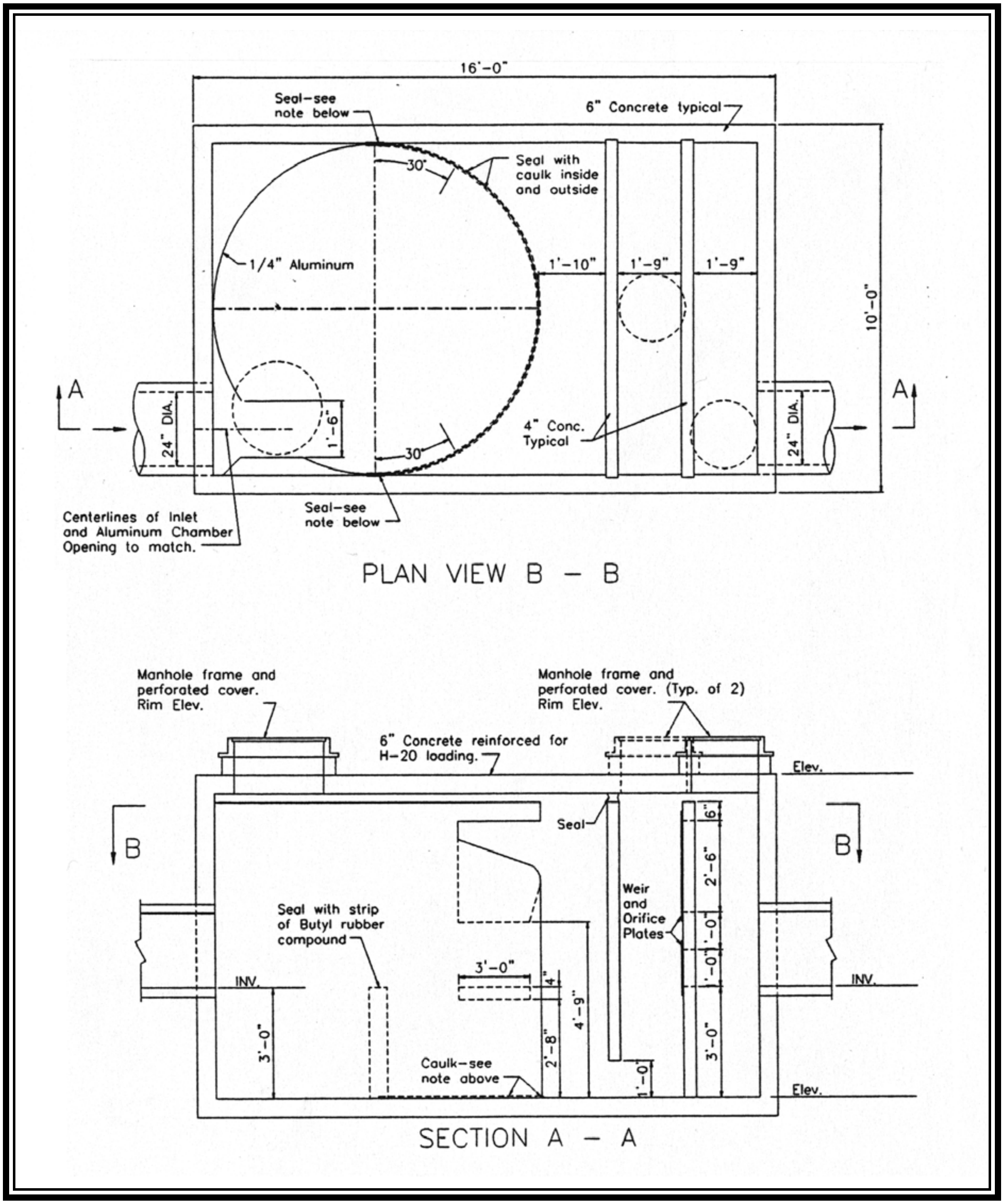
The first year of operation, Vortechnics recommends monthly inspections during periods of heavy contaminant loadings (e.g., winter sanding, soil disturbances, etc.). The inspection schedule can then be modified in subsequent years according to experience.

Clean-out of the *Vortechs System* with a vacuum truck is generally the best and most convenient method. Only the manhole cover above the grit chamber (the one farthest from the system outlet) needs to be opened to remove water and contaminants. As the grit chamber is pumped out, the oil and water drain back into it, so that oil scum, particulates and floatables are removed along with accumulated sediments. A pocket of water between the grit chamber and the flow control chamber seals the bottom of the oil barrier and prevents the loss of floatables to the outlet during cleaning.

**Contact:**

Tom Adams
Vortechnics
41 Evergreen Drive
Portland, ME 04103-1074
Phone: (207) 878-3662

**FIGURE 3.15-3**
*Vortechs Stormwater Treatment System - Model # 9000*



## MINIMUM STANDARD 3.15C

# DOWNSTREAM DEFENDER

### Description

The *Downstream Defender* consists of a concrete cylindrical structure with stainless steel internal components and a internal sloping base. Stormwater runoff enter the structure through a tangential inlet pipe which creates a swirling motion within the structure. The flow spirals down the perimeter of the structure, allowing heavier particles to settle out by gravity and drag forces exerted on the wall and base of the structure.

The base of the *Downstream Defender* is formed at a 30 degree angle. As the flow rotates about the vertical axis, solids are directed towards the base of the structure where they are stored in the collection facility. The steel internal components direct the main flow away from the perimeter and back up the middle of the vessel as a narrower spiraling column rotating at a slower velocity than the outer downward flow.

A dip plate is suspended from the underside of the component support frame. This dip plate serves two purposes: 1) it locates the shear zone, (the interface between the outer downward circulation and the inner upward circulation where a marked difference in velocity encourages solid separation), and 2) it establishes a zone between it and the outer wall where floatables, oil and grease are captured and retained after a storm. When the flow reaches the top of the structure, it is virtually free of solids and is discharged through the outlet pipe.

There are no moving parts and no external power requirements for the *Downstream Defender.*

**Overflow** - There is no overflow or bypass of larger storms. As the rate of runoff increases, the swirling motion keeps the sediments trapped in the collection facility, thus allowing the full range of storms to pass through the facility with minimum resuspension.

**Hydraulics** - The outlet flow from the *Downstream Defender* can be regulated with its associated valve, the *Reg-U-Flow Vortex Valve*. The valve can be adjusted to maximize the available storage in the upstream drainage system or upstream detention facility (if additional flow attenuation is required) by reducing the flow and backing the water up in the upstream system.

## Planning Considerations

A drop structure upstream of the *Downstream Defender* may be required to ensure that the flow enters into the structure at the appropriate elevation. The *Downstream Defender* comes in various sizes and is designed for all types of land uses. Depending on existing pipe invert elevations it can be installed on an existing pipe system (as a retrofit) or in a new system where water quality enhancement is required.

**Target Pollutants** – The *Downstream Defender* is designed to capture sediments, and grit (TSS), as well as floatable materials, including petroleum products. In addition, pollutant which adsorb to the particulates can also be trapped.

## Design Criteria

The design criteria for the *Downstream Defender* should be obtained from the manufacturer. All designs should be reviewed by the manufacture to insure that the system is correctly designed and sized.

## Maintenance and Inspections

A simple sump-vac procedure is periodically required to remove floatables and solids from the *Downstream Defender* collection facility. Regular inspections should be carried out over the first 12 months of operation to determine the rate of sediment and floatables accumulation. A probe may be used after storm events to determine the sediment depth in the collection facility. This information can then be used to establish a maintenance schedule. H.I.L. Technology, Inc. recommends inspection and clean-out at least twice a year.

A standard septic tank hose is not appropriate for the clean-out procedure. A *Vacall* with a 6-inch, or larger, hydraulic hose is required. The *Vacall* is capable of loosening compacted solids by reversing the vacuum pump prior to the sump- vac procedure.

Floatables should be removed prior to emptying the collection facility. The floatables access port is located between the concrete vessel wall and the dip plate. The collection facility access port is located directly over the center shaft.

**Contact:**

H.I.L. Technologies, Inc.
94 Hutchins Drive
Portland, ME 04102
Phone: 1-800-848-2706

**FIGURE 3.15-4**
***Downstream Defender - Section View***

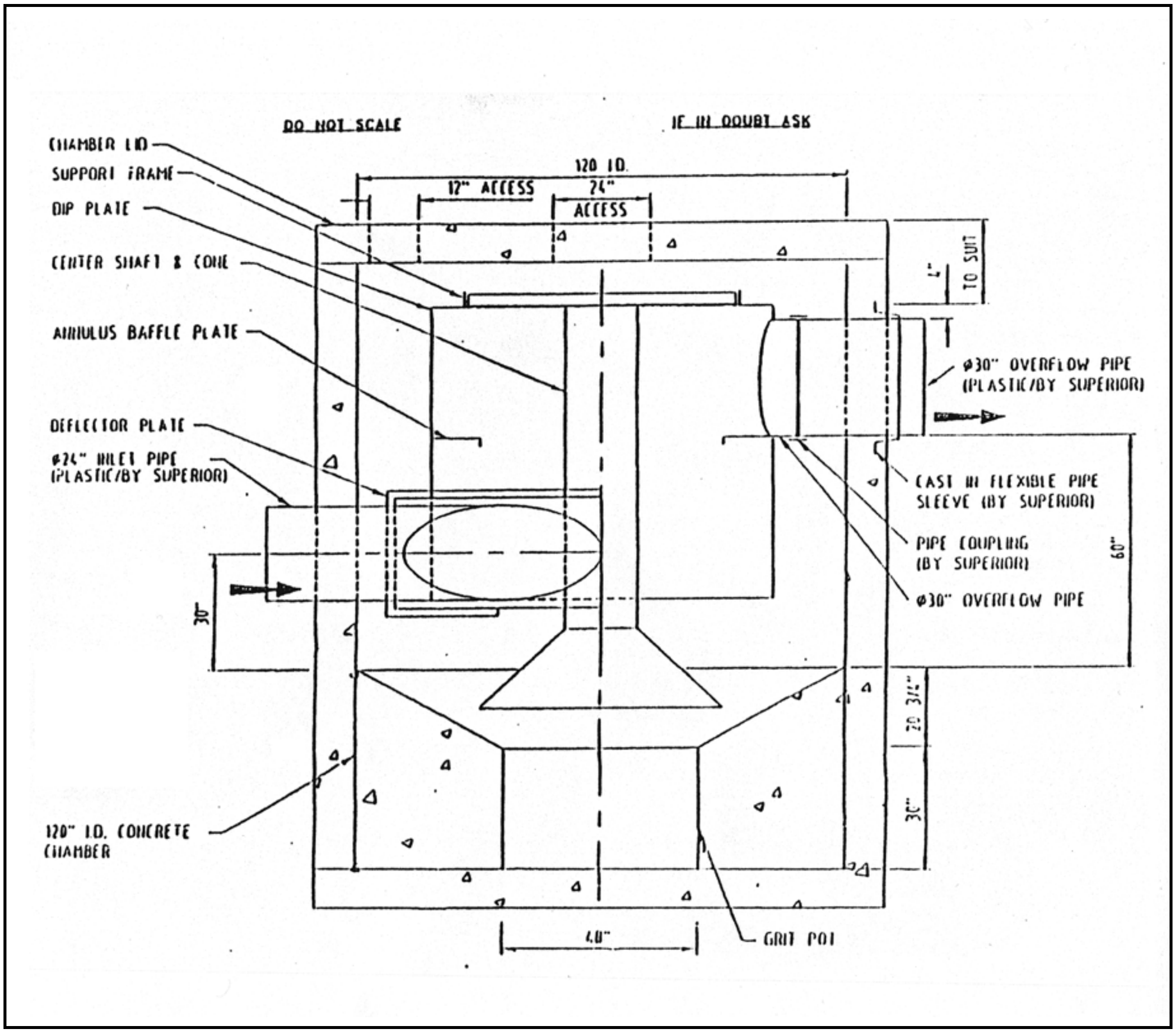
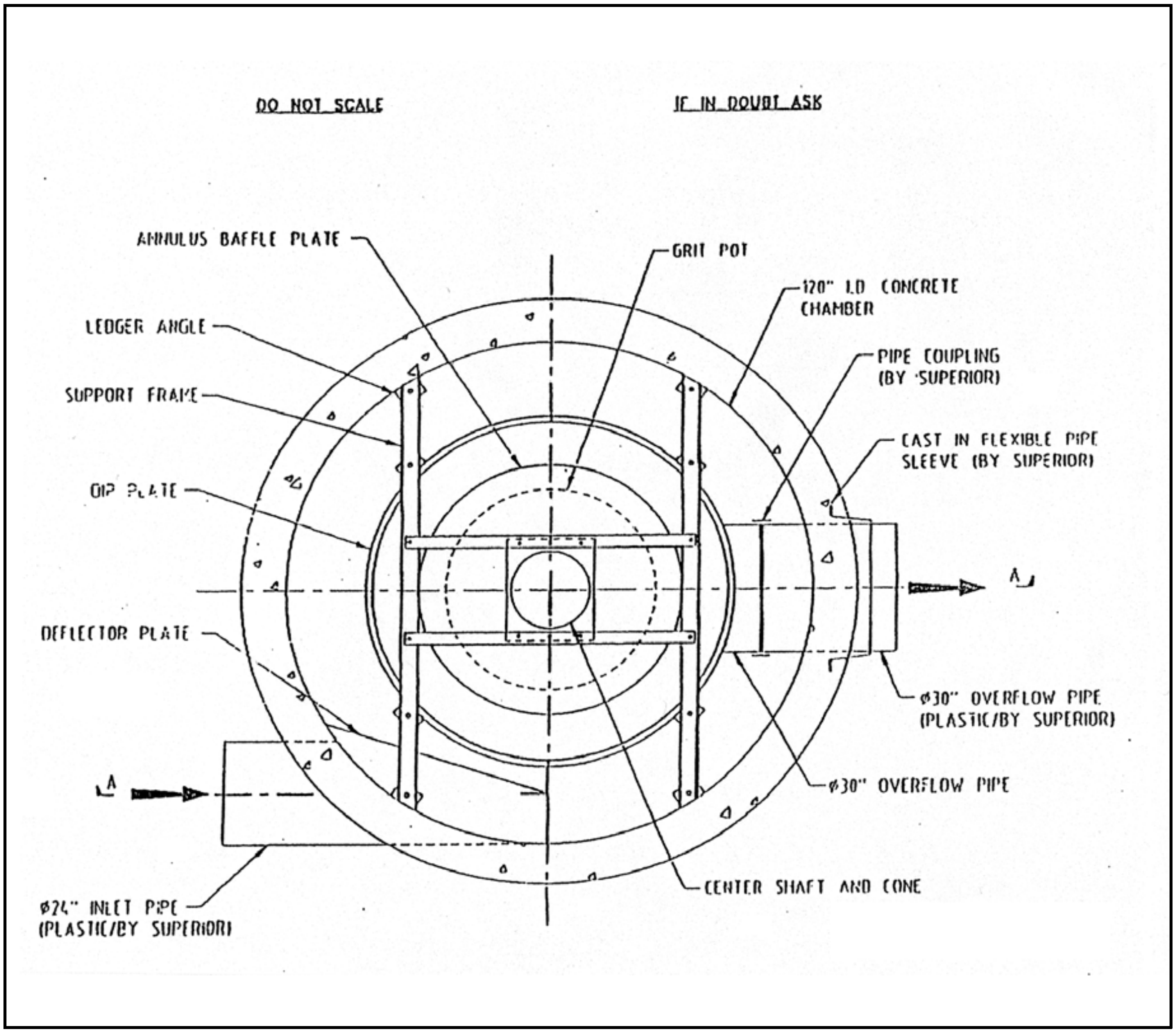


**FIGURE 3.15-5**
*Downstream Defender - Plan View*



## MINIMUM STANDARD 3.15D

# STORMTREAT SYSTEM

### Description

The *StormTreat System* captures and treats the first flush of runoff. An optional infiltration feature provides for the treatment of larger quantities of stormwater (beyond the first flush).

The system consists of a series of six sedimentation chambers and a constructed wetland which are contained within a modular 9.5-foot diameter tank. It is constructed of recycled polyethylene, which connects directly to existing drainage structures.

As stormwater enters the system, it is piped into sedimentation chambers where larger-diameter solids are removed. The internal sedimentation chambers contain a series of skimmers which selectively decant the upper portions of the stormwater in the sedimentation basins, leaving behind the more turbid lower waters. The skimmers significantly increase the separation of solids, as compared to conventional settling/detention basins. An inverted elbow trap serves to collect floatables, such as oils, within the inner tank. After moving through the internal chambers, the partially treated stormwater passes into the surrounding constructed wetland through a series of slotted PVC pipes.

The wetland is comprised of a gravel substrate planted with the bulrushes and other wetland plants. Unlike most wetlands constructed for stormwater treatment, the *StormTreat System* conveys stormwater into the subsurface of the wetland and through the root zone, where greater pollutant attenuation occurs through such processes as filtration, absorption, and biochemical reactions.

Precipitation of metals and phosphorus occurs within the wetland substrate, while biochemical reactions, including microbial decomposition, provide treatment of the stormwater prior to discharge through the outlet valve. An outlet control valve provides a variable holding time within the system and can be closed to contain a hazardous waste spill.

There are no moving parts and no external power requirements for the *StormTreat System*.

**Overflow** - There is no internal, large storm bypass within the *StormTreat System*. An overflow of the treated water is provided and is conveyed to a receiving channel or pipe system, or as option, the overflow can be directed into he surrounding soils for infiltration (if the soils meet the criteria for infiltration facilities - **Minimum Standard 3.10**). This feature can be enhanced by backfilling the excavation around the StormTreat System with 3/4" stone, similar to an infiltration trench with the StormTreat system providing pretreatment.

The flow into the *StormTreat System* is be regulated by the inflow pipe. A storage structure or basin may be used to temporarily hold the runoff until it can drain into the *StormTreat System.*

**Hydraulics** – The flow through the various filtering mediums is slow and, therefore, the backwater effects are high for this system. Flow through the system is gravity dependent such that a 4-foot difference in elevation is needed from the pavement surface to the discharge point. This may prove difficult on relatively flat sites.

## Planning Considerations

The *StormTreat System* can be configured in clusters of tanks to fit within limited areas and is designed for all types of land uses. The manufacturer recommends that a sump catch basin be placed prior to the StormTreat System in order to trap larger diameter sediments.

**Target Pollutants –** The *StormTreat System* is designed to capture sediment (TSS), fecal coliform bacteria, total petroleum hydrocarbons, total dissolved nitrogen, total phosphorus, lead, chromium, and zinc.

## Design Criteria

The design criteria for the *StormTreat System* should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is designed and sized correctly.

## Maintenance and Inspections

The *StormTreat System* requires minimal maintenance. Annual inspection is recommended to insure the system is operating effectively. During inspection the manhole should be opened, the burlap grit screening bag covering the influent line should be removed and replaced, and filters should be removed, cleaned, and reinstalled. Sediment should be removed from the system via suction pump once every 3 to 5 years, depending on local soil characteristics and catch basin maintenance practices.

**Contact:**
Mr. Scott Horsley
StormTreat Systems Inc.
90 Route 6A
Sextant Hill, Unit 1
Sandwich, MA 02563
ph. (508) 833-1033

**FIGURE 3.15-6**
*StormTreat System Tank*

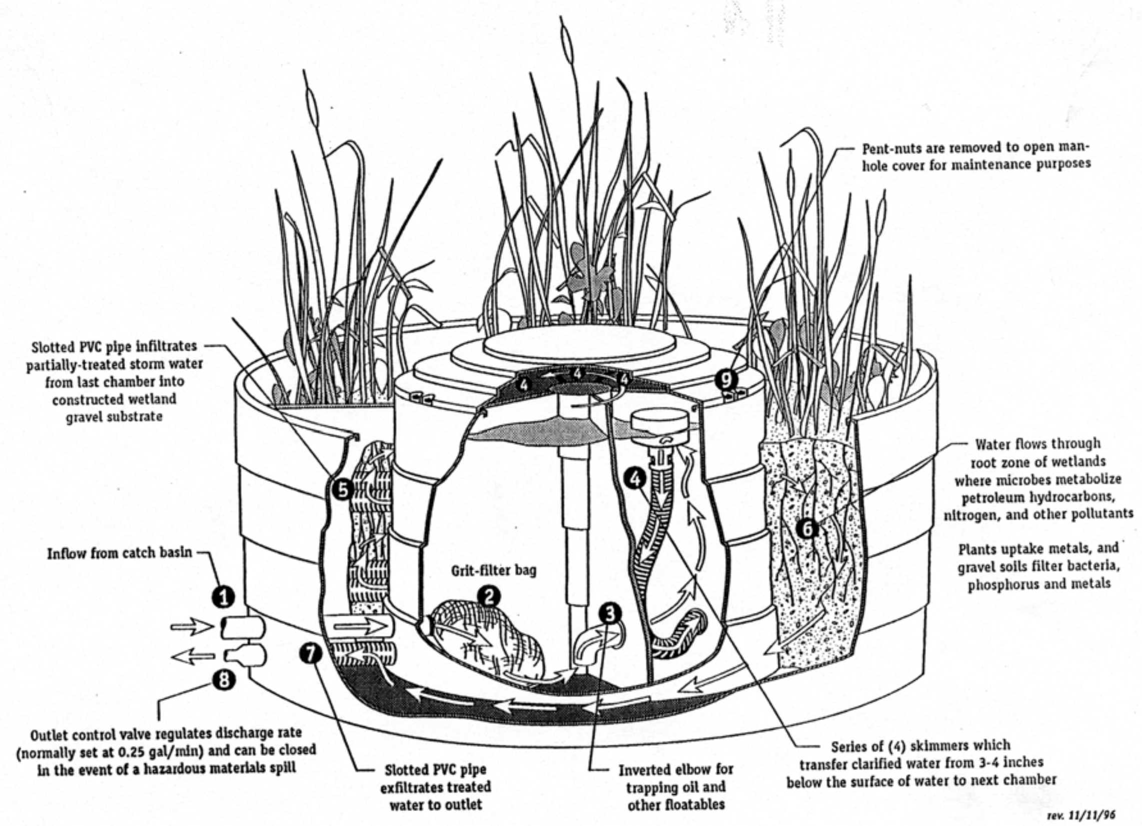
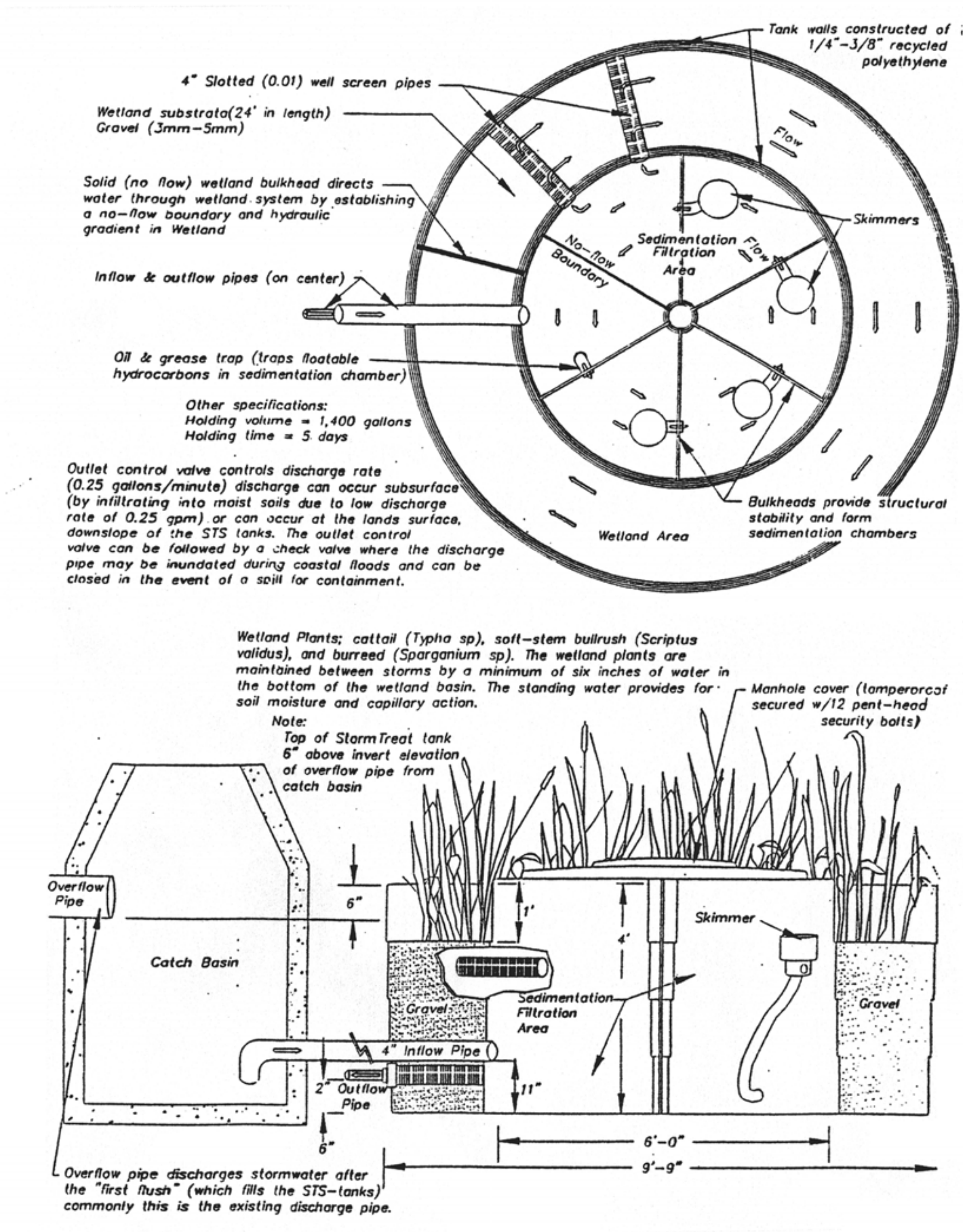


**FIGURE 3.15-7**
*StormTreat System*



## MINIMUM STANDARD 3.15E

# STORMFILTER

### Description

The *StormFilter* uses cylindrical rechargeable filter cartridges which hold a variety of filter media and can be customized by using different filter media to remove desired levels of sediments, phosphorus, nitrates, soluble metals, and oil & grease. Housed in standard size pre-cast or cast-in-place concrete vaults, the filter systems can be installed in-line, allowing stormwater to percolate through the cylindrical cartridges before discharging to an open channel drainage way. The *StormFilter* is equipped with scum baffles that trap floating debris and surface films, even during overflow conditions.

There are no external power requirements for the *CSF Stormwater Treatment System*. Moving parts are contained within the filter cartridges as part of the *priming system* discussed in the Hydraulics section.

**Overflow** – The *CSF system* is designed with an overflow that operates when the inflow rate exceeds the infiltration capacity of the filter media. The overflow consists of a weir wall inside the structure housing. Depending upon individual site characteristics, some filters are equipped with high- and/or low-flow bypasses. High-flow bypasses can be installed when the calculated peak storm event generates a flow which overcomes the overflow capacity of the filter.

**Hydraulics** – The hydraulics of the *StormFilter* are designed to maintain the design flow rate through the filter without pumps or other motorized devices. Each filter cartridge contains a float-actuated device called a *priming system* within the central drainage tube. This system primes the cartridges, which then develop a siphon inside the drainage tube. The siphon increases as the filter cartridges become progressively clogged to help maintain the design flow.

### Planning Considerations

The *StormFilter* is a structural BMP which can be easily installed in a parking lot or in fully developed areas as it does not require additional development space. However, consideration should be given to long term maintenance costs.

**Target Pollutants** – The *StormFilter* is designed to capture sediment (TSS), soluble metals, and oil and grease, nitrogen, and phosphorus. The various filter media can be selected to target pollutants of primary concern. The following filter media are available:

- Pleated fabric
- CSF leaf media
- Perlite
- Zeolite
- Granular activated carbon

According to the manufacturer, a combination of the pleated fabric and the zeolite media provides the best removal efficiencies for phosphorus and TSS.

## Design Criteria

The design criteria for the *CSF Stormwater Treatment System* should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is correctly designed and sized.

## Maintenance and Inspections

Maintenance requirements of the *CSF Stormwater Treatment System* are controlled by the amount of plugging of the filters caused by sediment accumulation. The filters are progressively loaded with sediment contained in runoff. At least one scheduled inspection of the filter must be undertaken to perform minor maintenance activities, which includes flow valve adjustment. The major maintenance activity is performed to rejuvenate the media and clean the system. Major maintenance activities may also be required in the event of a chemical spill or excessive sediment loading (due to site erosion or extreme storms). It is also good practice to inspect the system after severe storm events.

When the cartridges become too occluded with sediments, maintenance involves the removal of the exhausted cartridges and replacement with freshly charged cartridges. The time period between when the cartridges are initially installed and when they must be replaced is dependent upon site specific conditions and sediment loading.

As with other filtration systems, sediments will accumulate on the filter surface, eventually slowing the infiltration capacity. To reduce sediment loading to the surface of filters, it is recommended that the filters be used in conjunction with sediment reducing practices such as parking lot sweeping and catch basin sand traps.

**Contact:**

Mr. James H. Lenhart, P.E.
Stormwater Management
2035 Colombia Boulevard, NE
Portland, Oregon 97211
ph. (800) 548-4667

**FIGURE 3.15-8**
***StormFilter***

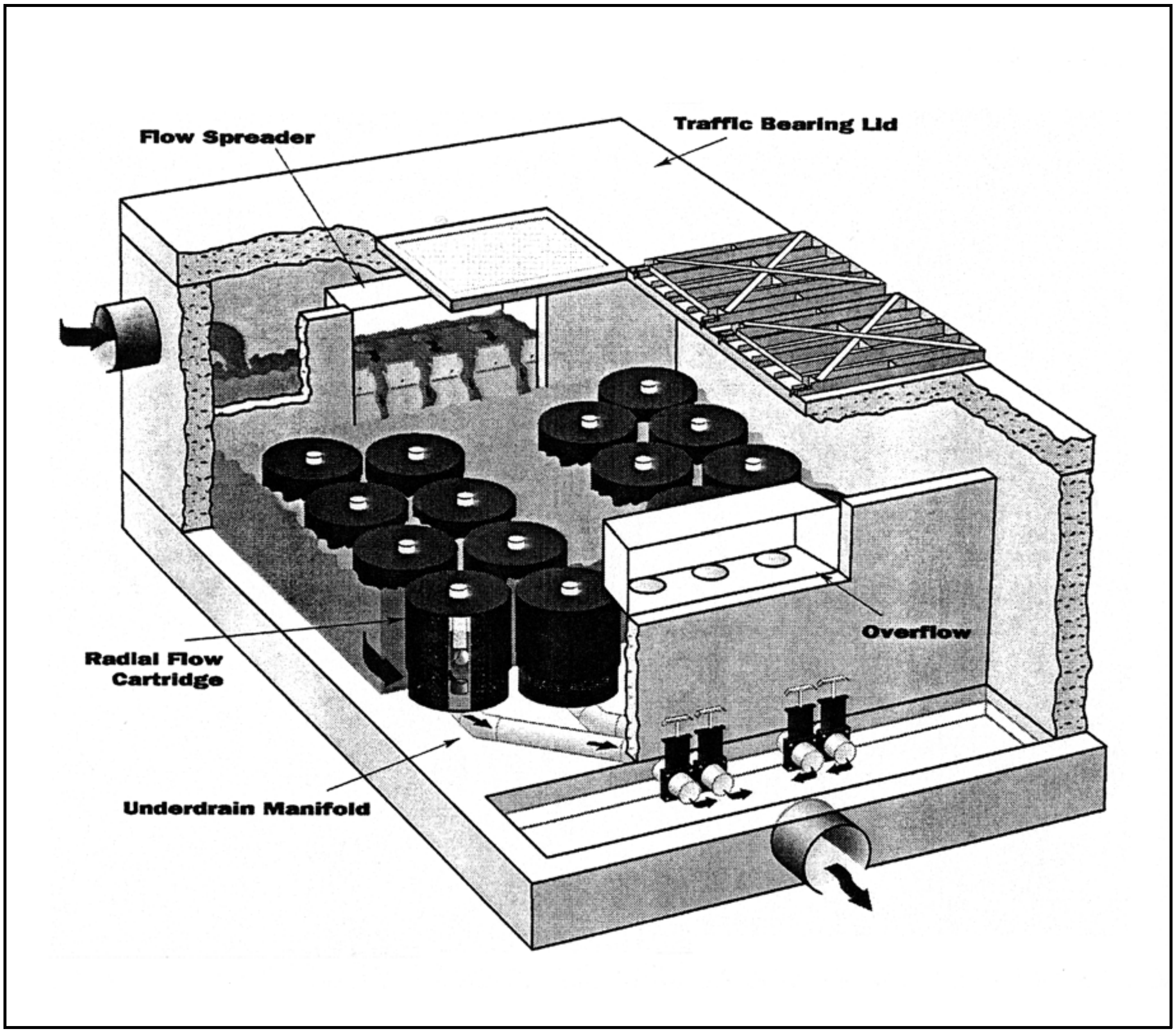
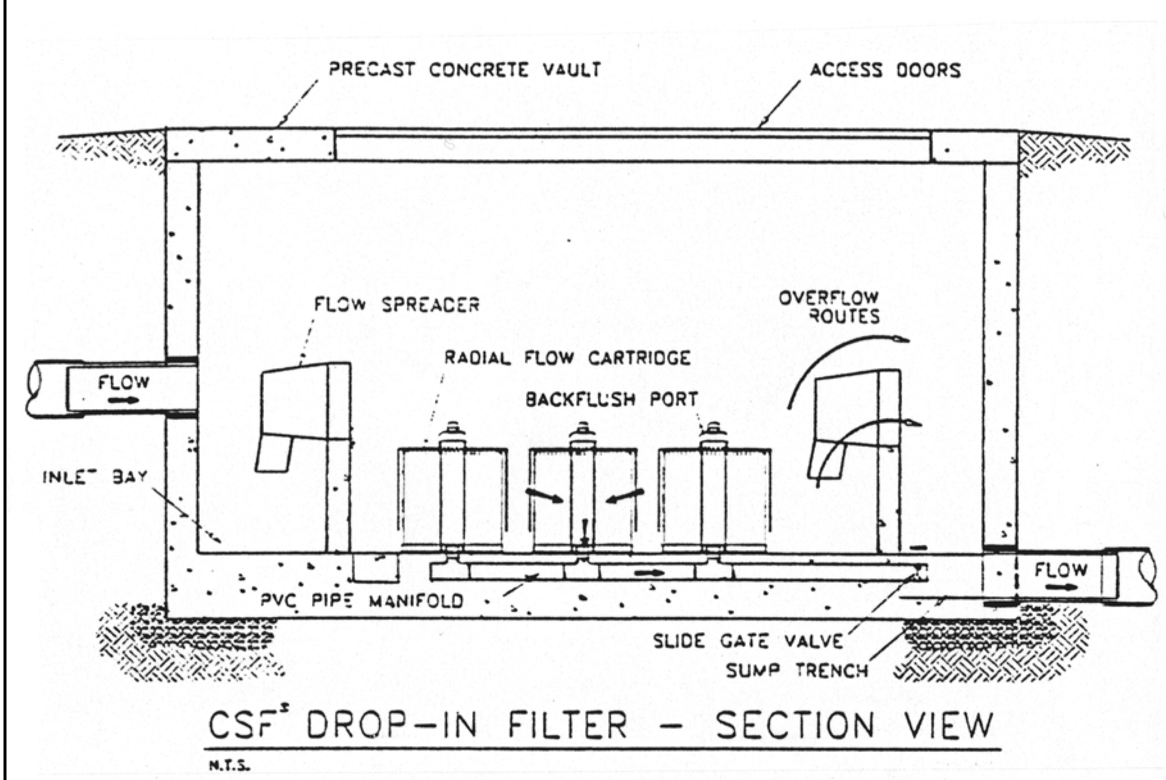


**FIGURE 3.15-9**
***StormFilter Drop-In Filter***



## MINIMUM STANDARD 3.15F

# BAYSAVER

### Description

The Bay Saver system is comprised of three main components: the Primary Separation Manhole, the Secondary Storage Manhole, and the BaySaver Separator Unit. The primary and secondary manholes are both standard precast concrete drop structures. The BaySaver Separator Unit is constructed of high-density polyethylene (HDPE).

Stormwater runoff enters the BaySaver system through the primary separation manhole. As the water flows into the manhole, the larger sediments settle to the bottom of the tank. **Figure 3.15-10** shows a profile of the primary manhole. The structure has a minimum water level at the elevation of the BaySaver's surface skimming weir. This weir is a trapezoidal shaped weir with a bottom width ranging from 3" to 6", and a flow depth of 9" to 18", depending on the size unit as required by the contributing drainage area. As water flows into the manhole, the surface water flows over the weir and is diverted to the storage manhole. This water carries with it floating pollutants (oils, for example), debris, and fine sediment particles.

The BaySaver Separator Unit incorporates three flow paths that water can take through the system. The trapezoidal surface-skimming weir diverts first flush and low flows into the second manhole for the most efficient treatment. As the water level rises in the primary separation manhole, more water flows over the weir. The majority of oils and fine sediments are removed by this flow path.

During a more intense storm, the BaySaver unit will also allow water to flow through the inverted 90E elbow pipes. The elbow pipes draw water from the middle of the primary separation manhole, with the intakes approximately four feet below the surface, and discharge directly to the system outfall. The water pulled by the elbows is free of floating contaminants and has had time for suspended sediments to settle out. By discharging this water, the BaySaver can continue full treatment of the surface flow in the second manhole.

If the flow becomes too great for the system to effectively treat, the BaySaver bypasses the treatment stages, conveying water directly from inlet to outlet. Elongated openings in the crown of the elbow pipes serve as pressure equalizers, significantly reducing flow through the submerged inlets of the elbow pipes during bypass. This reduction minimizes the resuspension and discharge of trapped contaminants from the primary manhole. Bypass flows also prevent water from flushing through the storage manhole, providing more protection against the risk of resuspension of fines and oils.

There are no moving parts and no external power requirements for the BaySaver.

**Overflow** - Large storm bypass is accomplished first by the two 90E inverted elbow pipes, and second by overflowing the top plate over the weir (set approximately at ½ the diameter of the separator unit).

**Hydraulics** - The separator unit and associated overflow pipes are sized according to the drainage area being served. The system should operate without creating a back water condition in the upstream drainage system.

## Planning Considerations

The BaySaver primary and secondary manholes are precast and come in three sizes depending on drainage area size. The system can be installed on an existing system (as a retro fit) or on a new system where water quality enhancement is required.

**Target Pollutants** - The BaySaver system is designed to capture sediment, total suspended solids (TSS) trash, organic material, and floatable oil and grease. In addition, many other urban pollutants which absorb to sediments and particles can also be trapped by the structure.

## Design Criteria

The design criteria for the BaySaver should be obtained from the manufacturer. All designs should be reviewed by the manufacturer to insure that the system is appropriately designed and sized.

## Maintenance and Construction

It is generally recommended that the system be maintained (full pump-out) once per year. This frequency may have to be adjusted to a shorter interval once loading rates are determined. Regular inspections will help determine the required frequency of cleaning. More frequent inspections are appropriate where oil spills occur regularly or a large volume of trash and debris are expected.

**Contact:**

BaySaver, Inc.
1010 Deer Hollow Drive
Mount Airy, Maryland 21771
Phone: (301) 829-6119

**FIGURE 3.15-10**
***BaySaver Primary Separation Manhole***

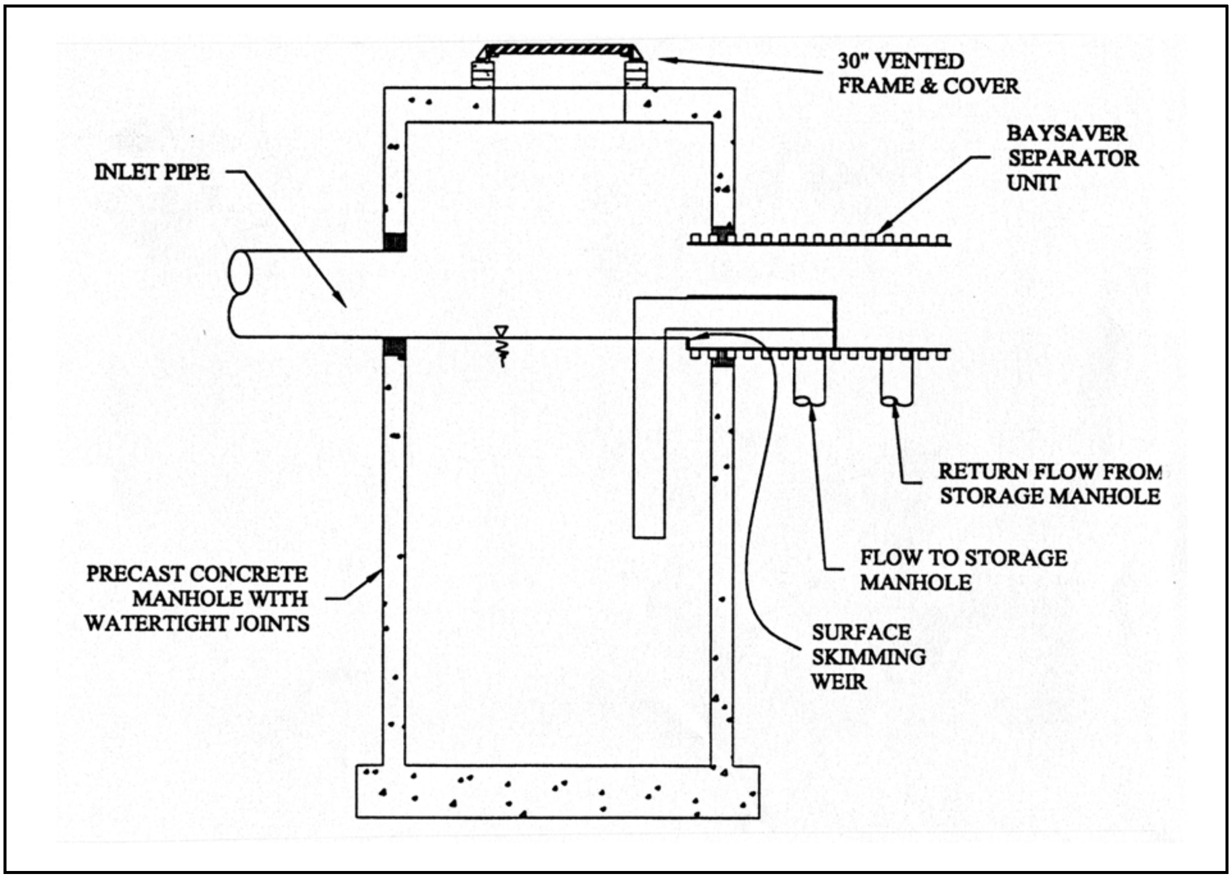
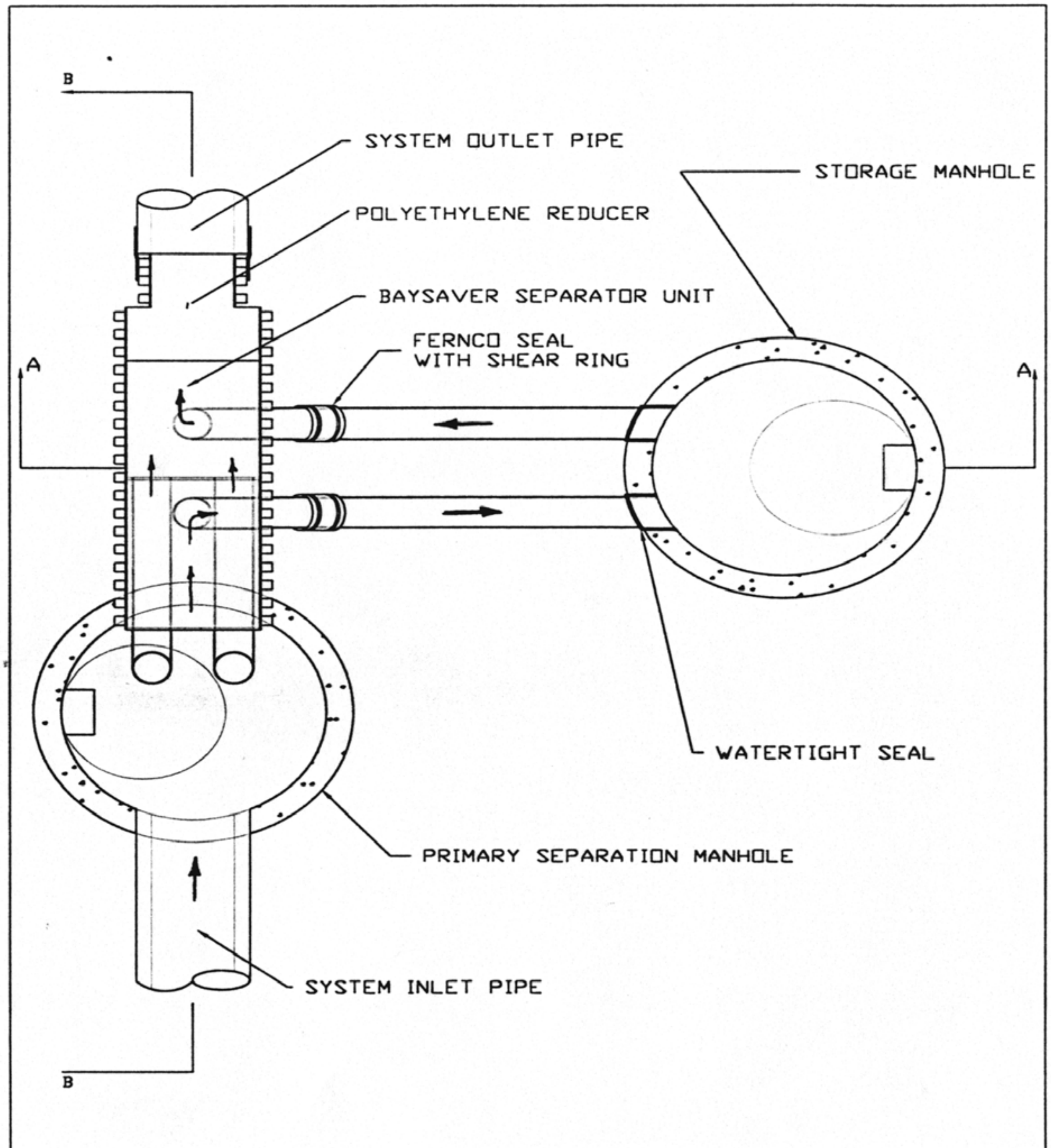


**FIGURE 3.15-11**
*BaySaver Plan View*




**Plan View**

**FIGURE 3.15-12**
*BaySaver Section A-A*

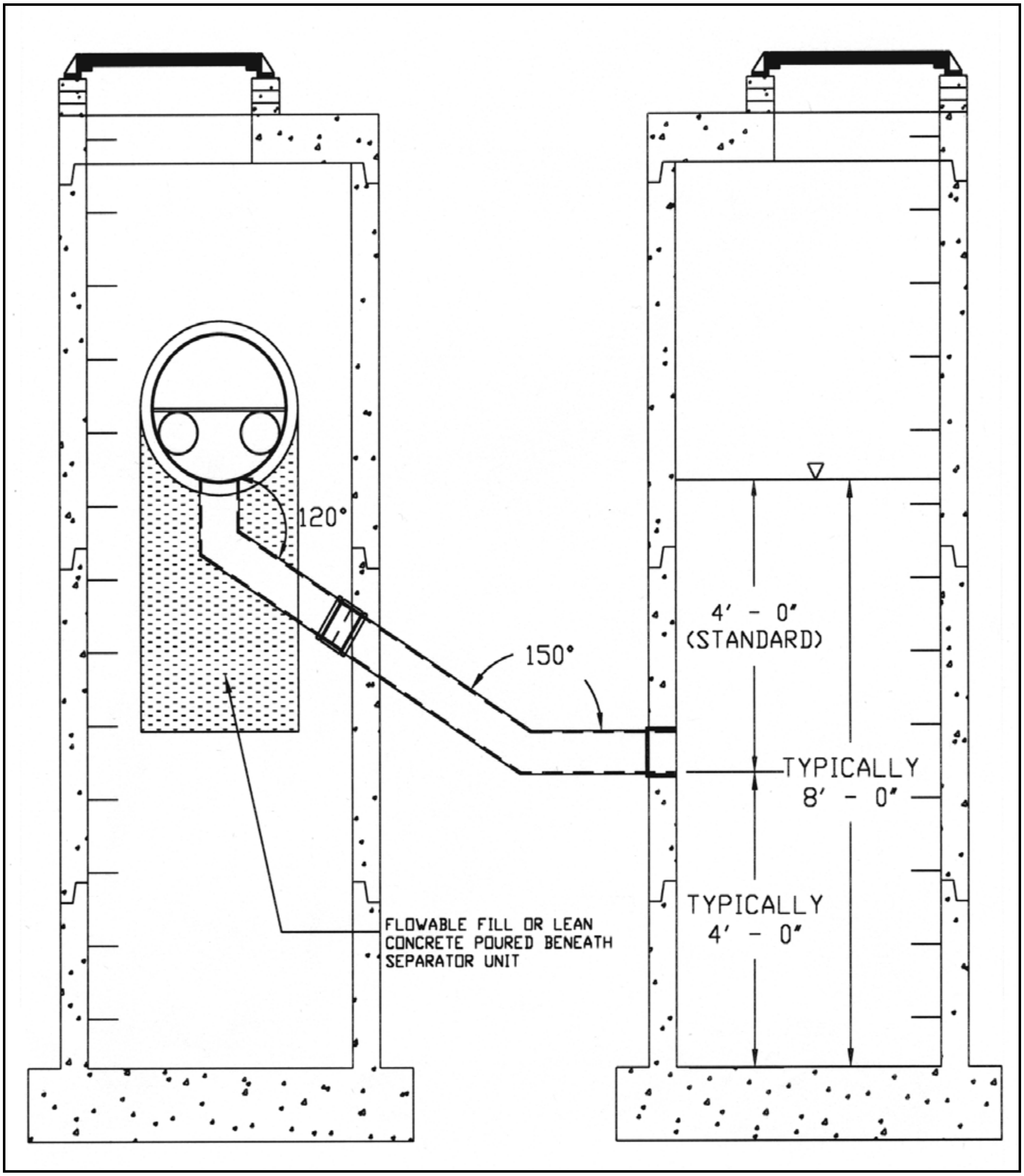
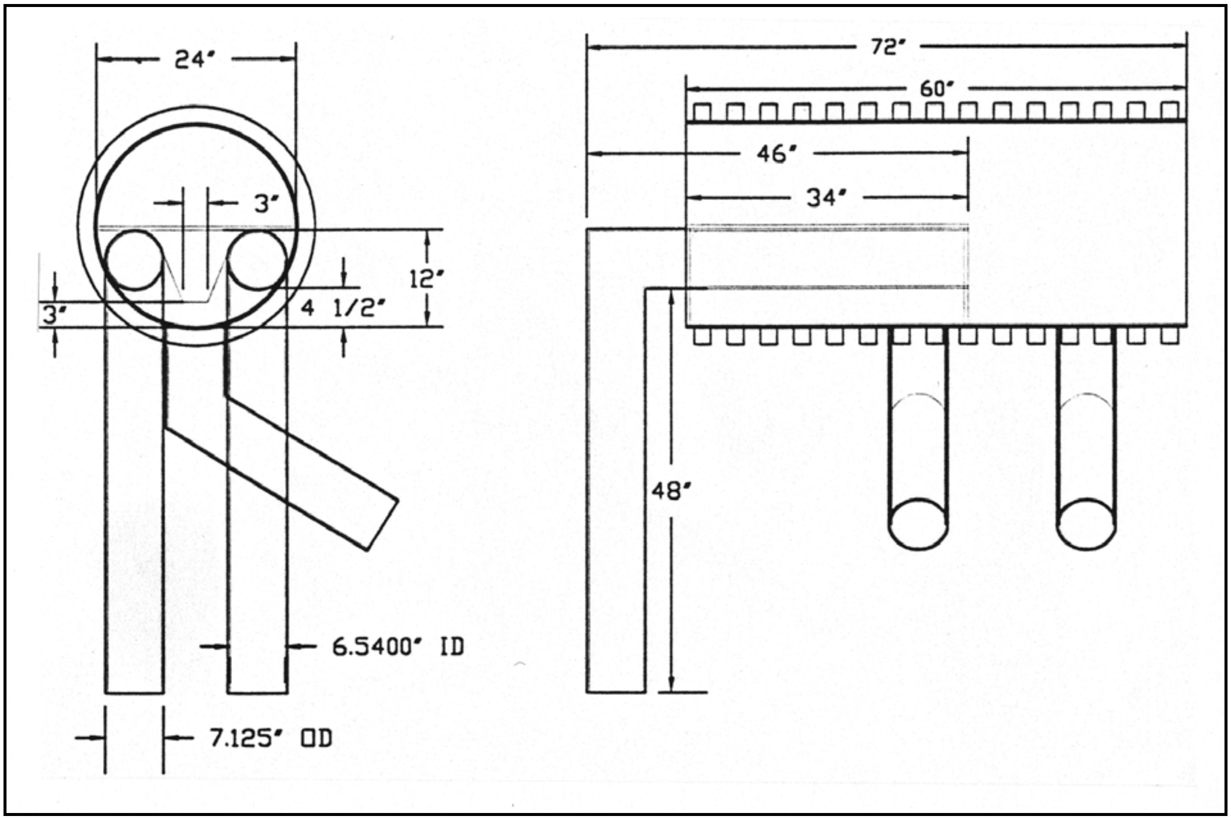


**FIGURE 3.15-13**
*BaySaver 1K Separator Unit*



Manufactured BMP Systems. Manufactured systems can be selected to address specific pollutant sources. This trench drain surrounds fuel handling area of a service station to direct any spills or otheridentified petroleum based contaminants to a manufactured system designed specifically for fuel or hydrocarbon containment. Note: fuel area is under cover which serves to limit the design flow entering the system.

# CHAPTER 3

## APPENDIX

# CHAPTER 3

# APPENDIX

**CONTENTS**

# APPENDIX 3A

Introduction - Checklists

## Design and Plan Review Checklists

Design and plan review checklists provide general guidance for both the designer and plan reviewer. Many items listed on the checklists may not apply to any given design and it is therefore up to the designer to indicate items as "*not applicable*" or "*NA*" as appropriate. Similarly, the reviewer must be able to distinguish which items are required based on the local conditions or requirements and verify the status of those items. These checklists serve as a tool for providing the designer with the necessary information needed to develop an approvable plan, as well as for providing the plan review authority with a consistent review procedure.

## Construction Inspections and As-Built Survey Checklists

The purpose of construction inspections and an as-built survey is to verify that constructed SWM facilities and associated conveyance systems have been built in accordance with the approved plan and design specifications. An as-built survey, including construction inspection logs should be provided prior to final site approval and release of the performance guarantee. This is in the best interest of the owner as well as the local program, since long term maintenance costs can increase significantly, if the facility is not built correctly. Also, there could be a problem that the system may not provide the quantitative and/or qualitative control, as prescribed by the approved plan. Liability issues arise if a downstream property owner is adversely affected and can prove that the facility is not per the approved plan.

### A. Construction Inspections

Adequate construction inspection of stormwater BMPs will usually require an on-site inspector to verify that the materials, methods, and placement, are in accordance with the approved plans and specifications. Critical components of the design; such as the anti-seep collar or filter and drainage diaphragm on the outlet conduit, the embankment foundation, riser footing, and other sub-surface components, must be examined for compliance to the design prior to being backfilled with the earthen embankment. The use of an on-site inspector will help to avoid delays by allowing the contractor to proceed with the earthwork rather than waiting for a scheduled (or non scheduled) inspection of a critical component.

Localities will usually provide regular inspections of SWM facilities under construction. The frequency of these inspections will vary based on the workload represented by active projects and the number of inspectors on staff. These inspections should verify that the contractor and on-site inspector are documenting the construction inspections in order to adequately substantiate the as-built certification. In the case of a local program requirement of inspections during critical portions of the construction, a signed inspection log by a qualified individual (other than the contractor) should be acceptable. Otherwise, the locality should establish a construction inspection schedule with the contractor prior to construction.

All inspection logs and other related information should be incorporated into a file for each individual project.

## B. As-Built Survey

Some as-built documentation must be obtained *during* the construction process, since some vital components are hidden in the final product. Therefore, construction inspections and inspection records are included in the as-built survey. For purposes of discussion, an as-built survey may be broken down into three components. These components are earthwork specifications, material specifications (other than earthwork) and a dimensions and elevations survey. The items noted within these components should be checked, and documentation be retained as needed to substantiate that the SWM BMP has been constructed in accordance with the approved plan and specifications. The following provides a discussion of the components of an as-built survey.

### 1. Earthwork Specifications

The acceptable completion of earthwork in the construction of a SWM facility is crucial in assuring that a facility is structurally sound. This category covers all aspects pertaining to the completion of earthwork for a facility. It is essential that specific elements of the construction inspection, as well as the pre-construction feasibility analysis of the soils, be documented. This may include compaction tests, inspections of the removal of unsuitable materials under and adjacent to the embankment foundation, construction of the cut off trench and other seepage control measures, compaction around the barrel, riser structure footing, and any other element that is hidden in the final condition. All work should be completed under supervision of a licensed geotechnical engineer. The inspection logs and test results should be included in the final as-built survey.

#### a. Geotechnical/Geophysical Testing

The examination of existing underlying strata indicates the composition of that strata and if that strata will support a SWM facility. For example, the presence of bedrock at the natural ground surface or in "cut" provides a plane of weakness that water may follow or exfiltrate to. This is especially critical in areas of karst. Also, the presence of organics or other unsuitable materials under the embankment and embankment footing may require additional excavation. This must be documented as having been completed.

Normally, in non-karst terrain (east of the Blue Ridge), simple geotechnical logs taken at the SWM site will provide adequate interpretative results. In karst west of the Blue Ridge, however, it is extremely useful that the testing be expanded to geophysical (seismic) evaluation. These tests provide images of underlying strata and indicate the presence of anomalies. This is critical since limestone geology exhibits extensive caves and cavities where ponding of runoff may exacerbate collapse of underlying cavities, which ultimately results in extremely expensive repairs.

**b. Fill Classification**

The geotechnical portion of the approved plan should provide a listing of soil classification types that are suitable for use at the project infill. Specialized criteria may also specify the classification of impermeable soil to be used for clay liners in areas of sandy soils or karst. Fill soils containing such materials as excessive or large rock, organic material or "fatty clay" (CH) classification are not acceptable due to the inability to achieve proper compaction or because of their shrink-swell properties. Verification must also be provided that the specifications for materials to be used in the construction of drainage and filter diaphragms have been complied with.

**c. Compaction**

The application of "lifts" in proper thickness and density is essential in attaining a stable SWM structure. The compaction of dam embankment to a percentage at or above the percent compaction specified in the approved plan and within the optimal range of moisture content assures that there will not be adverse settlement of the embankment. Careful compaction in areas adjacent to the barrel and seepage control measures is critical to eliminate excessive "void space" along the outlet barrel where the potential for embankment failure is high. Sufficient test results should be retained to document uniform compaction of the dam embankment and density/permeability of **existing soil formation and/or soils to be** used for liners (where applicable), in accordance with the approved plan.

**2. Material Specifications**

Construction materials may be classified as those items other than earthwork. A large number of component items needed for the construction of SWM facilities are grouped into this category. Some of these components must be inspected during installation. Materials would include, but not be limited to, concrete, reinforcing steel, concrete pipe, metal pipe, woodwork, masonry, and any other items that are applicable to the facility and satisfy all the requirements of the local program. The following provides a general discussion of some of the components of a SWM facility:

**a. Riprap and Aggregate**

The size distribution (diameter of aggregate), the amount of "fines" and integrity of rock may be factors, since aggregate sizing should be in accordance to the plan.

(1) Aggregate sizing plays a role in two distinct areas. In underground reservoir use, the size of aggregate dictates the amount of void space available for infiltration or retention/detention of runoff. In riprap use, the minimum size is critical in maintaining stability during high velocity flow, while a size in great excess of the stone specified may be as equally detrimental in regards to aesthetics and/or proper placement.

(2) The amount of fines contained within aggregate is generally a visual observation, although quarry delivery tags should bear out the specifications per VDOT specs. The percentage of fines generally is important where washed stone is to be utilized for an underground aggregate reservoir, or where the outlet protection of a facility is discharging into a stream or other sensitive area that is susceptible to turbidity.

(3) Rock integrity and shape is generally the visual observation that the aggregate used will meet specifications without long term decay. For example, sandstone does not make good riprap since it may be expected to disintegrate over time. Slate usually exhibits cleavage planes and therefore lays flat. When used for outlet protection, insufficient surface roughness of the slate may not dissipate concentrated flow energy.

**b. Control Structure**

There are an infinite number of design configurations for a control structure. Whatever the design, there should be project specifications for dimensions, strength and specific materials in accordance with the specifications found in Chapter 3, and any other local requirements. Appropriate documentation from the manufacturer should be retained (as applicable) to document each component. For example, pre-cast concrete risers normally arrive with as-built shop drawings that indicate specifications of the item furnished. Where components are constructed at the site, such as a cast in-place riser footing, test information and/or delivery tags from the concrete plant should be retained, while rebar reinforcement and dimensional information is documented in the construction log. Other items normally applicable to the control structure include:

(1) An outlet barrel, normally affixed to the control structure, is used to convey flow to an accepted discharge point. Items related to proper conduit installation include the procedure used in sealing joints of conduit together, the method of attachment to the control structure and the use of inlet and floor shaping (as applicable) within

the control structure.

There is also a need to inspect and document the existence, location and spacing of anti-seep collars, concrete cradle or other seepage control measures (at the outlet barrel) as specified in the approved plan. Documentation should include verification of critical dimensions, existence of reinforcement and indication of concrete mix strength. In the case of filter diaphragms, both earthwork and materials need to be **considered in installation.**

(2) Trash racks of varying design and construction are normally affixed to a control structure and in some cases inlets which "feed" the SWM facility. Visual observation (with inspection log entry) should indicate bar size, spacing grate configuration, and proper attachment to the control structure, or inlet and the application of rust resistant coating to the same where applicable.

**c. Geotextiles**

Synthetic fabrics are frequently specified for application beneath various components, under riprap or individually in spillways or for low flow channels. Proper selection of a manufacturer's product along with installation per the plan and/or manufactures directives is necessary to assure the performance intended. Method of installation should be observed and tag be provided from the product that verify compliance to the product specification given in the approved plan.

**d. Conveyance System Components**

One frequently overlooked portion of a SWM design is the components comprising the drainage system for the site. It is obvious that if the system is not built as intended by the approved plan, then the facility may not function accordingly. Critical items such as conveyance conduit diameter, slope, inlet and grate length/configuration are essential to insure that the required design storm (generated by contributory area) is adequately conveyed to the SWM facility for control and/or that non-contributory area is diverted away from SWM facilities.

**3. Dimensions and Elevations Survey**

The approved plan provides detailed information for specific elevations such as the inverts of the outlet conduits, control orifice and weir invert elevations, invert of emergency spillway, top of the dam, as well as pond bottom and slope of the same. Additional dimensional information exclusive of the control structure should also be provided. This could include the dimensions of the impoundment area at specific elevations and the top width and side slope of a dam embankment. The purpose of the as-built survey is to substantiate elevations and dimensions per the plan.

**G. As-Built Submittal Requirements**

As-built information should be documented and submitted in three forms: 1) a copy of the applicant's inspection log book. 2) a red-line revision of the approved SWM plan sheets and 3) a certification statement from a qualified individual regarding the conformance of the as-built to the approved plan.

1. A copy of the inspection log book should be kept at the project site. The log should document all aspects of the construction of the facility (with copies of applicable test results) to insure compliance with the approved plan. Any significant inconsistencies should immediately be reported to the engineer for evaluation and possible modification.

2. Red-line revision plans should be submitted upon completion of the facility. The plans should indicate any changes to the approved plan. Items that differ from the original approved plans and computations should be shown in red on both the plans and computations as follows:

    a. A red check mark must be made beside design values where they agree with actual constructed values.

    b. For changed values "line out" the design value and enter the actual value in red.

    c. Elevations to the nearest 0.1' are sufficient.

    d. A stage-storage summary table comparing the design values and the as-built values should be provided for facilities with storage volume.

3. The project owner should have those persons responsible for the inspection and implementation of the plan submit written certification that the SWM facility(s) and conveyance system have been built in accordance to the approved plan since this will cover underground facilities as well. Survey work during stake out and construction should be documented to verify underground volumes, elevations, pipe sizes, etc.

**<u>Operation and Maintenance Inspection Checklists</u>**

Once construction is completed, the SWM BMP takes on the role for which it was intended. Periodic site inspections are essential in order to monitor the effectiveness and to anticipate the maintenance needs of the BMP. It should be pointed out that not only the facility or BMP measure installed for stormwater control is important, but also the conveyance system to the BMP and the receiving channel immediately downstream of the BMP. The conveyance channel, curbing and/or storm sewer that convey flow to the facility or intentionally divert flows around it (as a part of the design) are all considered components and must function as intended.

The necessary frequency of inspections will vary with each facility based on the type of facility, size of the contributory drainage area, and development or land use conditions within the contributory drainage area. At a minimum, a full inspection should be performed at least once a year. Periodic inspections for trash and debris accumulation and general aesthetics should be performed after significant storm events.

The following checklists provide a guide for regular inspections of the various types of urban BMPs covered in this manual. The checklists are detailed enough for an inexperienced inspector or homeowner not familiar with the specific components of the facility. Checking the column provided under the *Investigate* heading for any given item indicates a potential problem that requires attention by a qualified individual to interpret the visual indicators for possible maintenance. The checklists should be signed, dated, and maintained at an accessible location such as with an official representative of the homeowners association, the individual or company contracted for maintenance, owner, etc.

# APPENDIX 3B

## Checklists - Detention, Retention, and Impoundment BMPs

## Design and Plan Review Checklist

Page 1 of 7

**Applicant:**_____________________________________ **Phone No.:**____________________
**Designer:**_____________________________________ **Phone No.:**____________________
**Project Name:** _____________________________________________________________
**Location:**_________________________________________________________________
**Type of Facility and Identification No.:**______________________________

***Plan status:***

____ approved

____ not approved

***Legend:***

T - Complete

Inc. - Incomplete/Incorrect

N/A - Not Applicable

**I. SUPPORTING DATA**

_____ Narrative describing stormwater management strategy including all assumptions made in the design.

**A. Drainage Area Map**

_____ Site and drainage area boundaries

_____ Off-site drainage areas

_____ Pre- and post-developed land uses with corresponding acreage

_____ Pre- and post-developed time of concentration flow paths

_____ Existing and proposed topographic features

_____ Drainage area appropriate for BMP

**B. Soils Investigation**

_____ Soils map with site and drainage area outlined

_____ Geotechnical report with recommendations and earthwork specifications

_____ Boring locations

  _____ Borrow area

  _____ Basin pool area

  _____ Embankment area: centerline principal spillway, emergency spillway , abutments

_____ Boring logs with Unified Soils Classifications, soil descriptions, depth to seasonal high groundwater table, depth to bedrock, etc.

_____ Compaction requirements specified

_____ Additional geophysical investigation and recommendations in Karst environment

## Design and Plan Review Checklist



## II. COMPUTATIONS

### A. Hydrology

_____ Runoff curve number determinations: pre- and post-developed conditions, with worksheets.

_____ Time of concentration: pre- and post-developed conditions, with worksheets.

_____ Hydrograph generation: pre- and post-developed condition for appropriate design and safety storms (SCS methods or modified rational-critical storm duration method)

### B. Hydraulics

_____ Specify assumptions and coefficients used.

_____ Stage-storage table and curve

_____ Riser structure and barrel

- _____ Weir/orifice control analysis for riser structure discharge openings
- _____ Weir/orifice control analysis for riser crest
- _____ Barrel: inlet/outlet control analysis
- _____ Riser/Outlet Structure flotation analysis (factor of safety = 1.25 min.).
- _____ Anti-seep collar or filter diaphragm design.
- _____ Outlet protection per VE&SCH Std.. & Spec. 3.18.
- _____ Provisions for use as a temporary sediment basin riser with clean out schedule & instructions for conversion to a permanent facility.

_____ Emergency spillway adequacy/capacity analysis with required embankment freeboard.

_____ Stage - discharge table and curve (provide equations & cite references).

_____ Storm drainage & hydraulic grade line calculations.

_____ Reservoir routing of post-development hydrographs for appropriate design storms (2-yr., 10-yr., or as required by watershed conditions) & safety storms (100-yr. or as required).

### C. Downstream impacts

_____ Danger reach study.

_____ 100 year floodplain impacts.

_____ "Adequate channel" calculations for receiving channel

_____ Provide downstream hydrographs at critical study points.

_____ Storm drainage plans for site areas not draining to BMP

- _____ Safe conveyance - MS-19
- _____ Areas compensated for in water quality performance-based criteria calculations

## Design and Plan Review Checklist

Page 3 of 7

**D. Water Quality**

_____ Impervious cover tabulation

_____ Technology-based criteria: proper selection of BMP based on impervious cover

_____ Performance-based criteria: pre- and post-developed pollutant load and pollutant removal requirement calculations (provide worksheets)

_____ Water quality volume for retention basin I, II, or III permanent pool

_____ Water quality volume for ext. detention and ext. detention enhanced with drawdown calculations

_____ Proper surface area/depth allocations for permanent pool/shallow marsh/constructed wetland

_____ Constructed stormwater wetland / shallow marsh

    _____ Adequate drainage area and/or base flow

    _____ Adequate pool volume

    _____ Adequate surface area

    _____ Allocation of surface area to depth zones

    _____ Maximum ponding depth over pool surface specified

**III. PLAN REQUIREMENTS**

**A. General Items**

_____ Plan view drawn at 1"=50' or less (40', 30', etc.)

_____ North arrow

_____ Legend

_____ Location plan and vicinity map

_____ Property lines

_____ Existing & proposed contours ( 2' contour interval min.)

_____ Existing features & proposed improvements (including utilities and protective measures)

_____ Locations of test borings

_____ Earthwork specifications

_____ Construction sequence for SWM basin and E&S controls

_____ Temporary erosion & sediment control measures

_____ Conveyance of base flow during construction

_____ Temporary and permanent stabilization requirements

    _____ Emergency spillway

    _____ Basin side slopes

## Design and Plan Review Checklist



    _____ Basin bottom

_____ Delineation of FEMA 100 year floodplain

_____ Plans sealed by a qualified licensed professional

**B.** **BMP Plan Views**

_____ Dimensions of basin features: perm. Pool, sediment forebay, embankment, etc.

_____ Location of all conveyance system outfalls into basin

    _____ Proper orientation to avoid short circuiting

    _____ Outlet protection per VE&SCH

_____ Top of bank & basin bottom elevations

_____ Elevations of permanent pool, water quality volume and max. design water surface elevations for all appropriate design storms and safety storms

_____ Side slope (H:V) of basin storage area and embankment (upstream and downstream slopes)

_____ Proper length-to-width ratio as specified in BMP design criteria

_____ **Pervious** low flow channel

_____ Sediment forebay

_____ Basin bottom slope

_____ Maintenance access to sediment forebay, riser structure, and one side of the basin ponding area

_____ Peripheral ledge for safety

_____ Aquatic Bench

_____ Shoreline protection

_____ Safety fence

_____ Riser and barrel materials and dimensions labeled

_____ Constructed stormwater wetland / shallow marsh

    _____ Basin liner specifications

    _____ Pool depth zones identified on plan

    _____ Pool geometry - wet/dry weather flow path

## Design and Plan Review Checklist



**C.** **BMP - Section Views & Related Details**

**1.** **Embankment (or dam) and Ponding Areas**

_____ Elevations of permanent pool, water quality volume and max. design water surface elevations for all appropriate design storms and safety storms

_____ Top of dam elevations- constructed height and settled height (10% settlement).

_____ Adequate freeboard

_____ Top width labeled

_____ Elevation of crest of emergency spillway

_____ Emergency spillway w/ side slopes labeled.

_____ Emergency spillway inlet, level, and outlet sections labeled

_____ Existing ground and proposed improvements profile along center line of embankment

_____ Existing ground and proposed improvements profile along center line of principal spillway

_____ Typical grading section through pond including typical side slopes with aquatic bench, safety ledge, shoreline protection, etc.

_____ Existing ground and proposed improvements along center line of emergency spillway

_____ Dimensions of zones for zoned embankment

**2.** **Seepage Control**

_____ Impervious lining

_____ Phreatic line (4:1 slope measured from the principal spillway design high water).

**a.** **Anti-seep Collar**

_____ Anti-seep collar (detail reqd..).

_____ Size (based upon 15% increase in seepage length).

_____ Spacing & location on barrel (at least 2' from pipe joint).

**b.** **Filter Diaphragm**

_____ Design certified by a professional geotechnical engineer.

**3.** **Foundation Cut Off Trench or Key Trench**

_____ Materials labeled

_____ Bottom width (4' min. or greater per geotech. report).

_____ Side slopes labeled (1:1 max. steepness).

_____ Depth (4' min. or as specified in geotechnical report)

## Design and Plan Review Checklist



**4. Multi Stage Riser and Barrel System**

_____ Materials labeled
_____ Bedding or cradle details provided
_____ Gauge & corrugation size for metal pipes specified
_____ Barrel diameter, inverts, and slope (%) labeled
_____ Outlet protection per VESCH, Std. & Spec. 3.18, 3.19 w/ filter cloth underlayment
_____ Crest elevation of riser structure shown
_____ Inverts and dimensions of control release orifices/weirs shown
_____ Structure dimensions shown
_____ Control orifice/weir dimensions shown
_____ Extended detention orifice protection (detail required for construction)
_____ Riser trash rack or screen (detail reqd.. for construction).
_____ Riser anti-vortex device (detail reqd.. for construction).
_____ Proper riser structure footing.
_____ Access to riser structure interior for maintenance.
_____ Basin drain pipe

**D. Landscape Plan**

_____ Planting schedule and specifications (transport / storage / installation / maintenance)
_____ Plant selection for planting zones 1thru 6
_____ Preservation measures for existing vegetation
_____ Top soil / planting soil included in final grading

**E. Maintenance Items**

_____ Person or organization responsible for maintenance.
_____ Maintenance narrative which describes the long-term maintenance requirements of the facility and all components.
_____ Facility access from public R/W or roadway.
_____ Maintenance easement.

## Design and Plan Review Checklist

Page 7 of 7

**COMMENTS**

________________________________________
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BY: ______________________________ DATE: __________

## Construction Inspection and As-Built Survey Checklist

Page 1 of 2

**Applicant**: ______________________________________ **Phone No**.:_______________
**Designer**:________________________________________ **Phone No**.:_______________
**Project Name**:____________________________________________________________
**Location**:_________________________________________________________________
**Contractor**:_______________________________________ **Phone No**.:_______________
**Permit No**.: ______________________
**Type of Facility and Identification No**. ________________________________________

A separate checklist is to be completed for separate BMPs, should more than one be used at a given project.

* Key - ( T ) If acceptable

( Inc. ) If not adequate, explanation at the end of a section is required

(NA) If not applicable

### I. INSPECTION LOGS and TEST DOCUMENTATION

#### A. Earthwork

_____ The results and interpretation of geo-physical testing in areas of karst formation (west of the Blue Ridge) or geo-technical analysis (boring log data) of underlying strata elsewhere in the state
_____ Verification of removal of all unsuitable material beneath dam embankment and footing
_____ Verification of fill classification/suitability for use in the embankment
_____ Verification of proper installation of cut-off trench
_____ Verification of soil impermeability for material used in the liner, and proper liner thickness
_____ Multiple compaction test results indicating adequacy throughout the embankment section including areas adjacent to the outlet conduit and any seepage control measures.
_____ Verification that underlying bedrock and/or the water table does not interfere with the impoundment
_____ Verification of dimensions of sub surface features such as the riser structure footing, anti seep collars, filter and drainage diaphragm, etc.

#### B. Materials

_____ Riprap size distribution and composition
_____ Inlet shaping (within the control structure and system manholes)
_____ Trash rack construction/coatings
_____ Trash rack; method of installation
_____ Shop drawings for control structure detailing dimensions, elevations, and reinforcing information
_____ Verification of structure reinforcement and water tight connections

## Construction Inspection and As-Built Survey Checklist

Page 2 of 2

_____ Low-flow channel lining
_____ Outlet barrel size/construction type/length
_____ Outlet protection
_____ Anti-vortex device

(Comments)
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

## II. DIMENSIONS and ELEVATIONS SURVEY (Red Lined Plan Sheets)

_____ Top width, and side slopes (profile) of dam embankment
_____ Inverts and slope (%) of outlet conduit
_____ Elevation and cross section of the emergency spillway
_____ Principal spillway profile including elevations and geometry of riser control orifices and/or weirs
_____ Cast-in-place control structure dimensions/elevations
_____ Riser crest and invert of control structure
_____ Outlet protection
_____ Contours of the ponding area
_____ Slope(s) of storm sewer system conduit with inverts in and out for each pipe
_____ Slope and cross-section of all on-site channels

(Comments)
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

## II. CERTIFICATIONS

_____ Certification's from manufacturers for materials used
_____ Seeding tickets and specifications
_____ Certification statement and seal by licensed professional indicating the as-built drawing is accurate, complete and constructed per the approved plan

## Operation and Maintenance Checklist

Page 1 of 3

| | YES / NO | REPAIR | INVESTIGATE | Inspector Name:_____________________________________________<br>Inspection Date: _____________________________________________<br>Type of BMP:_____________________________________________ |
|---|---|---|---|---|
| **Item** | | | | **Comments** |
| **I. EMBANKMENT** | | | | |
| **A. Crest** | | | | |
| **1. Visual settlement** | | | | |
| **2. Misalignment** | | | | |
| **3. Cracking** | | | | |
| **B. Upstream slope** | | | | |
| **1. Erosion** | | | | |
| **2. Adequate groundcover** | | | | |
| **3. Trees, shrubs or other** | | | | |
| **4. Cracks, settlements or bulges** | | | | |
| **5. Rodent holes** | | | | |
| **C. Downstream slope** | | | | |
| **1. Erosion** | | | | |
| **2. Adequate groundcover** | | | | |
| **3. Trees, shrubs or other** | | | | |
| **4. Cracks, settlements or bulges** | | | | |
| **5. Rodent holes** | | | | |
| **D. Abutments** | | | | |
| **1. Erosion** | | | | |
| **2. Seepage** | | | | |
| **3. Cracks** | | | | |

## Operation and Maintenance Checklist

Page 2 of 3

| | YES / NO | REPAIR | INVESTIGATE | InspectorName:________________________________ Inspection Date:__________________________________ Type of |
|---|---|---|---|---|
| E. Drainage, seepage control | | | | |
| 1. Internal drains flowing | | | | |
| 2. Seepage at toe | | | | |
| II.EMERGENCY SPILLWAY | | | | |
| 1. Eroding or backcutting | | | | |
| 2. Obstructed | | | | |
| 3. Leaking | | | | |
| 4. Operational | | | | |
| IV. PRINCIPAL SPILLWAY BARREL | | | | |
| 1. Seepage into conduit | | | | |
| 2. Debris present | | | | |
| 3. Displaced or offset joints | | | | |
| V. OUTLET PROTECTION/ STILLING BASIN | | | | |
| 1. Obstructed | | | | |
| 2. Adequate riprap | | | | |
| 3. Undercutting at outlet | | | | |
| 4. Outlet channel scour | | | | |
| VI. BASIN & UPLAND BUFFER AREA | | | | |
| A. Low flow channel | | | | |
| 1. Erosion | | | | |
| 2. Adequate vegetation | | | | |
| 3. Obstructed | | | | |

# Operation and Maintenance Checklist



| | YES / NO | REPAIR | INVESTIGATE | Inspector Name:________________________________________<br>Inspection Date:________________________________________<br>Type of BMP: ________________________________________ |
|---|---|---|---|---|
| **B. Basin bottom & side slopes** | | | | |
| **1. Erosion** | | | | |
| **2. Adequate stabilization** | | | | |
| **3. Sediment accumulation** | | | | |
| **4. Floating debris** | | | | |
| **5. High water marks** | | | | |
| **6. Shoreline protection** | | | | |
| **C. Inflow channels/pipes** | | | | |
| **1. Erosion** | | | | |
| **2. Adequate stabilization** | | | | |
| **3. Undercutting** | | | | |
| **D. Sediment forebay** | | | | |
| **1. Sediment accumulation** | | | | |
| **2. Stable overflow into basin** | | | | |
| **E. Upland landscaping** | | | | |
| **F. Aquatic landscaping** | | | | |

# APPENDIX 3C

Checklists - Infiltration BMPs

## Design and Plan Review Checklist

Page 1 of 5

**Applicant:**_________________________ **Phone No.:**______________
**Designer:**_________________________ **Phone No.:**______________
**Project Name:** ________________________________________
**Location:**____________________________________________
**Type of Facility and Identification No.:**____________________

***Plan status:***
____ approved
____ not approved

***Legend:***
T - Complete
Inc. - Incomplete/Incorrect
N/A - Not Applicable

**I. SUPPORTING DATA**

_____ Narrative describing stormwater management strategy including all assumptions made in the design.
(Infiltration basin, infiltration trench, roof downsput system, porous pavement)

**A. Drainage Area Map**

_____ Site and drainage area boundaries
_____ Off-site drainage areas
_____ Pre- and post-developed land uses with corresponding acreage
_____ Pre- and post-developed time of concentration flow paths
_____ Existing and proposed topographic features
_____ Drainage area appropriate for BMP

**B. Soils Investigation**

_____ Soils map with site and drainage area outlined
_____ Geotechnical report verifying suitability for infiltration (0.52"/hr $\leq f <$ 8.27"/hr)
_____ Boring locations
_____ Boring logs with Unified Soils Classifications
  _____ Soil descriptions
  _____ Depth to seasonal high groundwater (2' to 4' below design bottom of facility, min.)
  _____ Depth to bedrock (2' to 4' below design bottom of facility, min.)
  _____ Verification of absence of karst topography

## Design and Plan Review Checklist

Page 2 of 5

**C. Topographic Conditions**

_____ Meets minimum slope requirements

- _____ Porous pavement: s < 3% (20H:1V)
- _____ All other infiltration facilities: s < 20% (5H:1V)

**II. COMPUTATIONS**

**A. Hydrology**

_____ Runoff curve number determinations: pre- and post-developed conditions, with worksheets.

_____ Time of concentration: pre- and post-developed conditions, with worksheets.

_____ Hydrograph generation: pre- and post-developed condition for appropriate design and safety storms (SCS methods or modified rational-critical storm duration method)

**B. Hydraulics**

_____ 48 hour drain time provided

_____ Specify assumptions and coefficients used.

_____ Stage-storage table and curve (void ratio of 0.4 for stane storage)

_____ Riser structure and barrel for large storm overflow or bypass

_____ Emergency spillway adequacy/capacity analysis with required embankment freeboard for infiltration basins

_____ Storm drainage & hydraulic grade line calculations.

**D. Water Quality**

_____ Impervious cover tabulation

_____ Technology-based criteria: proper selection of BMP based on impervious cover

_____ Performance-based criteria: pre- and post-developed pollutant load and pollutant removal requirement calculations (provide worksheets)

_____ Water quality volume for desired target phosphorus removal efficiency.

## Design and Plan Review Checklist

Page 3 of 5

### III. PLAN REQUIREMENTS

#### A. General Items

_____ Plan view drawn at 1"=50' or less (40', 30', etc.)
_____ North arrow
_____ Legend
_____ Location plan and vicinity map
_____ Property lines
_____ Existing & proposed contours ( 2' contour interval min.)
_____ Existing features & proposed improvements (including utilities and protective measures)
_____ Locations of test borings
_____ Construction sequence
    _____ Infiltration BMP to be constructed after site work is completed and stabilization measures have been implemented
    _____ traffic control
_____ Temporary erosion & sediment control measures
_____ Temporary and permanent stabilization requirements
    _____ Infiltration basin emergency spillway
    _____ Infiltration basin side slopes
_____ Construction specifications
    _____ Infiltration basin bottom surface preparation
    _____ Infiltration trench bottom surface preparation
    _____ Infiltration trench filter fabric laydown
    _____ Infiltration trench aggregate placement
_____ Plans sealed by a qualified licensed professional

#### B. BMP Plan Views

_____ Dimensions of infiltration facility
_____ Location of all conveyance system outfalls into basin with pretreatment and outlet protection per VE&SCH

## Design and Plan Review Checklist

Page 4 of 5

_____ Infiltration basin

- _____ Top of bank & basin bottom elevations
- _____ Elevations of water quality volume and max. design water surface elevations for all appropriate design storms and safety storms
- _____ Side slope (H:V) of basin storage area and embankment (upstream and downstream slopes)
- _____ Sediment forebay
- _____ Maintenance access to sediment forebay and riser structure

_____ Safety fence

_____ Observation well

### C. BMP - Section Views & Related Details

### 1. Infiltration Basin

_____ Elevations of water quality volume and max. design water surface elevations for all appropriate design storms and safety storms

_____ Top of dam elevations- constructed height and settled height (10% settlement).

_____ Adequate freeboard

_____ Top width labeled

_____ Elevation of crest of emergency spillway

_____ Principal/emergency spillway w/ side slopes labeled.

_____ Principal/emergency spillway inlet, level, and outlet sections labeled

_____ Existing ground and proposed improvements profile along center line of embankment

_____ Existing ground and proposed improvements profile along center line of principal spillway

_____ Typical grading section through basin

_____ Existing ground and proposed improvements along center line of emergency spillway

_____ Dimensions of zones for zoned embankment

_____ Foundation Cut Off Trench or Key Trench

- _____ Materials labeled
- _____ Bottom width (4' min. or greater per geotech. report).
- _____ Side slopes labeled (1:1 max. steepness).
- _____ Depth (4' min. or as specified in geotechnical report)

## Design and Plan Review Checklist

Page 5 of 5

**2. Infiltration Trench**

_____ Dimensions provided

_____ Backfll material specified

    _____ Stone storage: clean VDOT No. 1 Open Graded Course Aggregate or equal

    _____ Bottom sand layer: VDOT Fine Aggregate, Grading A or B

_____ Filter Fabric

_____ Observation well

**3. Porous Pavement**

_____ Subgrade preparation

_____ Aggregate

    _____ Filter course: clean VDOT No. 57 Open Graded Course Aggregate or equal

    _____ Reservoir course: clean VDOT No. 3 Open Graded Course Aggregate or equal

    _____ Sand layer: VDOT Fine Aggregate, Grading A or B

_____ Porous asphalt surface course

**E. Maintenance Items**

_____ Person or organization responsible for maintenance.

_____ Maintenance narrative which describes the long-term maintenance requirements of the facility and all components.

_____ Facility access from public R/W or roadway.

_____ Maintenance easement.

**COMMENTS**

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

BY: ________________________________ DATE: _______

**Construction Inspection and As-Built Survey Checklist**

Page 1 of 2

**Applicant**: ______________________________________ **Phone No**.:_______________
**Designer**:_______________________________________ **Phone No**.:_______________
**Project Name**:_____________________________________________________________
**Location**:_________________________________________________________________
**Contractor**:______________________________________ **Phone No**.:_______________
**Permit No**.: ______________________
**Type of Facility and Identification No**. ________________________________________

A separate checklist is to be completed for each BMP, should more than one be used at a given project.

* Key - ( T ) If acceptable

( Inc. ) If not adequate, explanation at the end of a section is required

(NA) If not applicable

## I. INSPECTION LOGS and TEST DOCUMENTATION

### A. Flow splitter / Overflow

_____ Overflow invert at correct elevation

_____ Inflow pipe plugged prior to full site stabilization

### B. Earthwork

_____ The results and interpretation of geo-physical testing in areas of karst formation (west of the Blue Ridge) or geo-technical analysis (boring log data) of underlying strata elsewhere in the state

- _____ Infiltration rate of soils
- _____ Depth to seasonal watertable
- _____ Depth to bedrock

_____ Verification of removal of all unsuitable material beneath dam embankment and footing

_____ Verification of fill classification/suitability for use in the embankment

_____ Verification of proper installation of cut-off trench

_____ Multiple compaction test results indicating adequacy throughout the embankment section including areas adjacent to the outlet conduit and any seepage control measures.

_____ Verification that underlying bedrock and/or the water table does not interfere with the impoundment

_____ Verification of dimensions of sub surface features such as the riser structure footing, anti seep collars, filter and drainage diaphragm, etc.

### B. Materials

_____ Stone aggregate size, composition, and placement

_____ Filter fabric placement

## Construction Inspection and As-Built Survey Checklist

Page 2 of 2

**C. Sequence of Construction**

_____ Site stabilization prior to facility construction
_____ Traffic control

(Comments)

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**II. DIMENSIONS and ELEVATIONS SURVEY (Red Lined Plan Sheets)**

_____ Invert and diameter/geometry of flow splitter, overflow pipes, and channels
_____ Top width, and side slopes (profile) of dam embankment
_____ Dimensions of storage area
_____ Elevation and cross section of the emergency / principal spillway
_____ Outlet protection
_____ Contours of the ponding area
_____ Slope and cross-section of all on-site channels

(Comments)

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

II. **CERTIFICATIONS**

_____ Certification's from manufacturers for materials used
_____ Seeding tickets and specifications
_____ Certification statement and seal by licensed professional indicating the as-built drawing is accurate, complete and constructed per the approved plan

## Operation and Maintenance Checklist

Page 1 of 2

**Date____________________**

**Project___________________________________ Site Plan / SUP Number _____________**
**Location___________________________________ Date Placed in Service _______________**
**Date of Last Inspection ____________ Inspector __________________________________**
**Owner/Owner's Representative _________________________________________________**
**"As Built" Plans available: Y / N**

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **1. Debris cleanout** | | |
| Contributing areas clean of debris | ________ | ________ |
| Filtration facility clean of debris | ________ | ________ |
| Inlets and outlets clear of debris | ________ | ________ |
| **2. Vegetation** | | |
| Contributing drainage area stabilized | ________ | ________ |
| No evidence of erosion | ________ | ________ |
| Area mowed and clippings removed | ________ | ________ |
| **3. Clogging** | | |
| No evidence of surface clogging | ________ | ________ |
| Observation well clear of water within 48 hrs of storm event | ________ | ________ |
| **4. Structural components** | | |
| No evidence of structural deterioration | ________ | ________ |
| Any grates are in good condition | ________ | ________ |
| No evidence of spalling or cracking of structural parts | ________ | ________ |

# Operation and Maintenance Checklist

Page 2 of 2

**Site Plan/SUP Number ______________________ Date: ___________________________**

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **6. Outlets/overflow spillway** | | |
| Good condition, no need for repair | ___________ | ____________ |
| No evidence of erosion (if draining into a natural channel) | ___________ | ____________ |
| **8. Overall function of facility** | | |
| No evidence of flow bypassing facility | ___________ | ____________ |
| No standing water | ___________ | ____________ |

**Action to be taken**:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair.

No action necessary. Continue routine inspections_________

Correct noted facility deficiencies by___________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on_____________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:__________________

________________________________________

Signature of inspector

# APPENDIX 3D

Checklists - Intermittent Sand Filters

## Construction Inspection and As-Built Survey Checklist

Page 1 of 3

**Date______________**

**Project_________________________________** **Site Plan / SUP Number ___________**

**Location_________________________________** **Date BMP Placed in Service _________**

**Individual(s) Conducting the Inspection___________________________**
**"As Built" Plans available Y / N**

**Warning:** If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented. If filtration facility is in a completely enclosed vault, OSHA Confined Space Entry procedures must be followed.

| | Satisfactory | Observed and Confirmed by (Initial) |
|---|---|---|
| **1. Flow Splitter** | | |
| Overflow invert at correct elevation | ________ | __________ |
| Inflow pipe to filter plugged with watertight seal prior to site stabilization | ________ | __________ |
| **2. Filter Shell (** Note: Separate structural inspections of the filter shell must be conducted and documented during construction) | | |
| Specified number and type of manhole covers and hatches installed | ________ | __________ |
| No evidence of structural defects ("honeycombing", etc) | ________ | __________ |
| Access ladders installed as specified | ________ | __________ |
| Shell completely cleaned of construction debris, dirt, etc. | ________ | __________ |
| Dewatering drain meets specs and holds water | ________ | __________ |
| Dewatering drain penetration sealed with specified water stop | ________ | __________ |
| **3. Watertight Integrity Test of Filter Shell** | | |
| Watertight plug installed in outflow pipe | ________ | __________ |
| Elevation of shell bottom observed at ___________ ft. | ________ | __________ |
| Filled with water to bottom of top slab at ___________(Time/date) | ________ | __________ |
| Top of water elevation observed at __________ ft. | ________ | __________ |
| Observed 24-hour drawdown at _____________ (Time/date) | ________ | __________ |
| Top of water elevation after drawdown observed at __________ ft. | ________ | __________ |
| Footprint of wetted shell (from drawings) is _____________ $ft.^2$ | | |
| Volume of water lost (footprint x elevation drop) = ___________ $ft.^3$ | | |
| Volume of initial water (footprint x depth of water) = __________ $ft..^3$ | | |
| Percent of initial volume lost = ________ % | ________ | __________ |

**Note:** If shell had ≤ five % water loss, the shell is satisfactory. If the shell had > five % water loss, find and seal leaks and retest until five % limit is achieved.

## Construction Inspection and As-Built Survey Checklist

Page 2 of 3

Site Plan/SUP Number ______________________ Date: __________________________

| | Satisfactory | Observed and Confirmed by (Initial) |
|---|---|---|
| **4. Basin(s) and Basin Liner(s) (Where Applicable)** | | |
| Basin(s) graded in conformance with plan | ________ | ________ |
| Basin liner material(s) conforms to specifications (attach 6" x 6" sample) | ________ | ________ |
| Basin liner installation(s) conforms to plans & specifications | ________ | ________ |
| **5. Collector System** | | |
| Collector pipes meet specs and hole patterns are correct | ________ | ________ |
| Collector pipes wrapped in geotextile meeting specs (attach labeled 6" x 6" sample) | ________ | ________ |
| Specified galvanized hardware cloth installed over weepholes (if used) | ________ | ________ |
| Collector gravel meets specs and is installed to design depth | ________ | ________ |
| Pea gravel (if used) meets spec and is installed to design depth | ________ | ________ |
| Geotextile fabric beneath sand meets spec (attach labeled 6" x 6" sample) and is lapped at least 6" up all 4 sides | ________ | ________ |
| **6. Filter Components** | | |
| Filter sand meets specifications (attach lab report showing gradation, effective size and uniformity coefficient) | ________ | ________ |
| Filter sand installed to design depth, hydraulically compacted on ______________ (Date) , and refilled to design depth | ________ | ________ |
| Filter top geotextile (if used) meets spec (attach labeled 6" x 6" sample) and is lapped up all four sides | ________ | ________ |
| Filter top ballast(if used) meets specs and is installed to design depth | ________ | ________ |
| **7. Clearwell** | | |
| Clearwell is free of construction debris and dirt | ________ | ________ |
| Outflow pipe invert is at the design elevation | ________ | ________ |
| Pump (where applicable) meets specs (attach catalog cuts) | ________ | ________ |
| Wiring (where applicable) is in waterproof conduits **(Note:** electrical wiring requires separate building code inspection) | ________ | ________ |
| Panel box (where applicable) is well marked (attach wiring diagram) | ________ | ________ |
| **8. Upflow Gravel Prefilter (where used)** | | |
| Bottom grate meets spec and installed at design elevation | ________ | ________ |
| Bottom geometries (if used) meets spec and properly installed | ________ | ________ |
| Large bottom stone meets spec and installed to design depth | ________ | ________ |
| Pea gravel meets spec and installed to design depth | ________ | ________ |

## Construction Inspection and As-Built Survey Checklist

Page 3 of 3

Site Plan/SUP Number ________________ Date: ____________________________

| | Satisfactory | Observed and Confirmed by (Initial) |
|---|---|---|
| **9. Monitoring Manholes (where required)** | | |
| Manhole shells and covers conform to specs | ________ | ________ |
| Inflow and outflow pipe slopes are as specified | ________ | ________ |
| Straight pipe runs through manholes are as specified (no bends) | ________ | ________ |
| Manholes and pipes are flushed clean | ________ | ________ |

**Note:** If any of the answers under items 1 - 9 above are checked unsatisfactory, a time frame shall be established for their correction or and a reinspection shall be scheduled. A new form shall be completely filled out at the time of the reinspection. Only the form documenting completely satisfactory performance shall be submitted to the governing jurisdiction for certification. All persons initialing this form shall complete the table below:

| Initial | Full Name | Signature | Title/Position and Organization |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**CERTIFICATION:** Based on the above, I certify that the Best Management Practice covered by this report is constructed in accordance with the approved Final Site Plan and as designed.

________________________________

(Signature)

________________________________

(Typed Name and Title)
(Place professional seal on certification)

## Operation and Maintenance Checklist

Page 1 of 2

**Date____________________**

**Project___________________________________ Site Plan / SUP Number _____________**
**Location___________________________ Date Placed in Service: ___________**

**Date of Last Inspection __________ Inspector ______________________________________**
**Owner/Owner's Representative _____________________________________________**
**"As Built" Plans available: Y / N Sand Filter Type: ______________________________**

**Warning:** If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented. If filtration facility is in a completely enclosed vault, OSHA Confined Space Entry Procedures must be followed.

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **1. Debris cleanout** | | |
| Contributing areas clean of debris | ________ | ________ |
| Filtration facility clean of debris | ________ | ________ |
| Inlets and outlets clear of debris | ________ | ________ |
| **2. Vegetation** | | |
| Contributing drainage area stabilized | ________ | ________ |
| No evidence of erosion | ________ | ________ |
| Area mowed and clippings removed | ________ | ________ |
| **3. Oil and grease** | | |
| No evidence of filter surface clogging | ________ | ________ |
| Activities in drainage area minimize oil & grease entry | ________ | ________ |
| **4. Water retention where required** | | |
| Water holding chambers at normal pool | ________ | ________ |
| No evidence of leakage | ________ | ________ |
| **5. Sediment deposition** | | |
| Filtration chamber clean of sediments | ________ | ________ |
| Water chambers not more than ½ full of sediments | ________ | ________ |

## Operation and Maintenance Checklist

Page 2 of 2

**Site Plan/SUP Number ______________________ Date: __________________________**

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **6. Structural components** | | |
| No evidence of structural deterioration | ________ | ________ |
| Any grates are in good condition | ________ | ________ |
| No evidence of spalling or cracking of structural parts | ________ | ________ |
| **7. Outlets/overflow spillway** | | |
| Good condition, no need for repair | ________ | ________ |
| No evidence of erosion (if draining into a natural channel) | ________ | ________ |
| **8. Overall function of facility** | | |
| No evidence of flow bypassing facility | ________ | ________ |
| No noticeable odors outside of facility | ________ | ________ |
| **9. Pump (Where Applicable)** | | |
| Catalog cuts and wiring diagram for pump available | ________ | ________ |
| Waterproof conduits for wiring appear to be intact | ________ | ________ |
| Panel box is well marked | ________ | ________ |
| No evidence of pump failure (excess water in pump well, etc.) | ________ | ________ |

**Action to be taken**:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair.

No action necessary. Continue routine inspections____________

Correct noted facility deficiencies by______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on____________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:________________

__________________________________

Signature of inspector

# APPENDIX 3E

Checklists - Bioretention

## Plant Selection and Site Consideration Checklist

Page 1 of 2

**Date**______________

### I. General Site Information

**Site Plan / SUP Number** ____________________

Project Name__________________________________________________

Size of development_____________________________________________

Drainage area size_______________________________________________

### II. Plant Material Layout Considerations

A. Site Design Considerations

Importance of aesthetics__________________________________________________________
__________________________________________________________________________

Important visual characteristics (foliage, form, etc.)____________________________________
__________________________________________________________________________

Visibility and traffic considerations________________________________________________
__________________________________________________________________________

Other safety issues______________________________________________________________

Conflict with any structural components of site (proposed powerlines, pipes)________________
__________________________________________________________________________

General comments_______________________________________________________________
__________________________________________________________________________

**Plant Selection and Site Consideration Checklist**

Page 2 of 2

Site Plan/SUP Number _______________ Date:______________

**B. Ecological Factors**

Insect and disease infestation on or near site____________________________________________
___________________________________________________________________________

Wind exposure____________________________________________________________________

Sun exposure_____________________________________________________________________

Effects upon bioretention area from adjacent plant communities_____________________________
___________________________________________________________________________

Wildlife benefits be included in plant material layout_______________________________________
___________________________________________________________________________

## Construction Inspection and As-Built Checklist

Page 1 of 2

**Date______________**

**Project________________________________ Site Plan / SUP Number _______________**
**Location_____________________________ Date BMP Placed in Service _____________**

**Individual(s) Conducting the Inspection_________________________________**
**"As Built" Plans available: Y / N**

**Warning:** If any bioretention facility component has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

| | Satisfactory | Observed and Confirmed by (Initial) |
|---|---|---|
| **1. Flow Splitter or Overflow Drain** | | |
| Overflow Invert at correct elevation | ________ | ________ |
| Inflow pipe to filter plugged with watertight seal prior to site stabilization (where applicable) | ________ | ________ |
| **2. Basin(s) and Basin Liner(s) (Where Applicable - Bioretention Filters)** | | |
| Basin(s) graded in conformance with plan | ________ | ________ |
| Basin liner material(s) conforms to specifications (attach 6" x 6" sample) | ________ | ________ |
| Basin liner installation(s) conforms to plans & specifications | ________ | ________ |
| **3. Collector System(Where Applicable--Bioretention-Filters and Green Alleys)** | | |
| Collector pipes meet specs and hole patterns are correct | ________ | ________ |
| Collector pipes wrapped in geotextile meeting specs (attach 6" x 6" sample) | ________ | ________ |
| Specified galvanized hardware cloth installed over weepholes | ________ | ________ |
| Collector gravel meets specs and is installed to design depth | ________ | ________ |
| Pea gravel beneath sand meets spec and is installed to design depth | ________ | ________ |
| **4. Sand and Planting Soil Components** | | |
| Filter sand meets specifications (attach lab report showing gradation, effective size and uniformity coefficient) | ________ | ________ |
| Filter sand installed to design depth | ________ | ________ |
| Planting soil meets design specifications | ________ | ________ |
| Planting soil installed to design depth, hydraulically compacted on ______________ (Date) , and refilled to design depth | ________ | ________ |

## Construction Inspection and As-Built Checklist

Page 2 of 2

| | Satisfactory | Observed and Confirmed by (Initial) |
|---|---|---|
| **5. Bioretention Plant Materials** | | |
| Plants meet size and variety specifications | ______ | ______ |
| All plants installed per landscape plan | ______ | ______ |
| Mulch or cover crop installed according to plans and specifications | ______ | ______ |
| **6. Clearwell Manhole (Where Applicable--Bioretention Filters and Some Green Alleys)** | | |
| Clearwell is free of construction debris and dirt | ______ | ______ |
| Outflow pipe invert is at the design elevation | ______ | ______ |
| Outflow pipe is capped with orifice drilled to design size | ______ | ______ |
| **7. Monitoring Manholes (where required)** | | |
| Manhole shells and covers conform to specs | ______ | ______ |
| Inflow and outflow pipe slopes are as specified | ______ | ______ |
| Straight pipe runs through manholes are as specified (no bends) | ______ | ______ |
| Manholes and pipes are flushed clean | ______ | ______ |

**Note:** If any of the answers under items 1 - 9 above are checked unsatisfactory, a time frame shall be established for their correction or and a reinspection shall be scheduled. A new form shall be completely filled out at the time of the reinspection. Only the form documenting completely satisfactory performance shall be submitted to the governing jurisdiction for certification. All persons initialing this form shall complete the table below:

| Initial | Full Name | Signature | Title/Position and Organization |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**CERTIFICATION:** Based on the above, I certify that the Best Management Practice covered by this report is constructed in accordance with the approved Final Site Plan and as designed.

______________________________

(Signature)

______________________________

(Typed Name and Title)
(Place professional seal on certification)

## Operation and Maintenance Inspection Checklist

Page 1 of 2

**Date**________________________________ **Time**____________________________

**Project**_____________________________________ **Site Plan / SUP Number** _______________

**Location**_________________________________________________

**Date Placed in Service:** _________________________ **Date of Last Inspection:** _____________

**Individual Conducting the Inspection** ___________________________________

**(Owner)** ____________________________________________________________

**"As Built" Plans available: Y / N**
**Bioretention Facility Type: ____ Infiltration; _____ Filter; _____Green Alley**

**Warning**: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented. If filtration facility is in a completely enclosed vault, OSHA Confined Space Entry Procedures must be followed.

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **1. Debris cleanout** | | |
| Contributing areas clean of debris | ________ | ________ |
| Bioretention facility clean of debris | ________ | ________ |
| Inlets and outlets clear of debris | ________ | ________ |
| **2. Drainage Area Stabilization** | | |
| Contributing drainage area stabilized | ________ | ________ |
| No evidence of erosion | ________ | ________ |
| Area mowed and clippings removed | ________ | ________ |
| **3. Oil and grease** | | |
| No evidence of filter surface clogging | ________ | ________ |
| Activities in drainage area minimize oil & grease entry | ________ | ________ |
| **4. Overflow Structure** | | |
| Overflow grate/throat clear of debris | ________ | ________ |
| Any grates are in good condition | ________ | ________ |
| No evidence of erosion (if draining into a natural channel) | ________ | ________ |

## Operation and Maintenance Inspection Checklist



**Site Plan/SUP Number** ______________________ **Date:** __________________________

| | Satisfactory | Unsatisfactory |
|---|---|---|
| **5. Bioretention Planting Soil** | | |
| No evidence of planting soil erosion | ________ | ________ |
| Bioretention basin clean of sediments | ________ | ________ |
| **6. Organic Layer** | | |
| Mulch covers entire area (NO voids) and to specified thickness | ________ | ________ |
| Mulch is in good condition | ________ | ________ |
| **7. Plants** | | |
| Specified number and types of plants still in place | ________ | ________ |
| No dead or diseased plants | ________ | ________ |
| No evidence of plant stress from inadequate watering | ________ | ________ |
| No evidence of deficient stakes or wires | ________ | ________ |

**NOTE:** Diseased plants must be treated by a qualified professional. Deficient stakes or wires must be replaced. Dead plants or plants diseased beyond treatment must be replaced by plants meeting original design specifications. New plants must be watered every day for the first 14 days after planting. Reinspections must be scheduled to occur following this period.

**Action to be taken:**

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair.

No action necessary. Continue routine inspections______________

Correct noted facility deficiencies by________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on_____________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:__________________

____________________________________________

Signature of inspector